

Collecting in Japan The Case for Hickories Untangling Roots Waking Well in the Anthropocene

SPRING 2024

The Nature of Trees
Arnoldia

HAMAMELIS "ARNOLD PROMISE"



Look Up

By Matthew Battles

Walking through the landscape to my office one morning last fall, I happened on a new sign between Willow Path and Meadow Road:

LOOK UP
You are entering
one of the most diverse collections
of maples in the world.

The word “diversity” caught my attention. I’ve spent much of my career in and around collections—before arriving at the Arboretum, I worked in libraries, archives, and museums at Harvard and elsewhere—and usually, “diversity” wasn’t the first word we used to describe them. Collections are “wide-ranging” or “focused” or “preeminent”—above all, “comprehensive.” Here in the Arboretum, what does *diverse* mean?

In terms of species count, the genus *Acer*, which comprises the maples, is a middling taxon. *Quercus* numbers some 500 species of oak (469, according to *Plants of the World*); *Acacia*, another tree-predominant genus, boasts more than a thousand. These genera pale in comparison to *Astragalus*—the milkvetches—which leads the list with more than 3000 species. With about 130 species, by contrast, *Acer* is far from the most diverse—if species count is our chosen marker of diversity.

We’re talking about *biodiversity*, which is a term of fairly recent coinage. Diversity mattered to Darwin, who used the word to describe variation in wild and domestic settings. In the 1872 edition of *Origin of Species*, for instance, he notes that “the number and diversity of inheritable deviations of structure, both those of slight and those of considerable physiological importance, are endless.” With the rise of ecology in the early twentieth century, “biodiversity” began to take familiar conceptual shape. Writing in 1916 about the flora of the Southwestern U.S. for *Scientific American*, botanist J. Arthur Harris celebrates the region’s richness and variety. To say that the desert “contains a flora rich in genera and species and of diverse geographic origin or affinity,” he writes, “is entirely inadequate as a description of its real *biological diversity*” (my emphasis). Harris marvels at how deep this biodiversity goes: “(D)istinctions between species are not solely of the kind that can be drawn or photographed or ascertained by inspection of that sacred and

indispensable mummy, the type specimen,” he observes. “The species of plants are not merely externally dissimilar, but inherently very diverse; they are not merely morphologically differentiated but physiologically very distinct; they are to be distinguished not merely by their external form, but by their methods of reaction to the various factors of their environment.”

So diversity scales from the physiological to the morphological to the ecological. How to hold it all? “Comprehensive,” a word with roots in taking and gathering, suggests that a collection is completable. In his 1753 *Species Plantarum*, Carl Linnaeus estimated that there were no more than 10,000 species of plants in the world—as book historian Molly Hardy has pointed out, he designed his herbarium cabinet to accommodate this fixed number. A 2022 study found 376,366 species of vascular plants have been validly described—likely a fraction of the actual number. The herbarium needs a lot of cabinets.

Given spiraling diversity, collectors must take a selective approach. With the addition of *Acer capillipes*, which Michael Dosmann and Miles Sax brought back from their recent trip to Japan (see “Science and Spirit in the Forests of Central Honshu,” beginning on page 18), our *Acer* collection now holds 63 species—roughly half the number in the genus. But species inventory is only part of the mission. As Harris observed more than a century ago, species “are not merely externally dissimilar, but inherently very diverse.” We are still learning that diversity runs deep, extending beyond form to physiology and ecological relation. In the Arboretum, this diversity factors into collection, propagation, and planting decisions—and the landscape becomes not only a repository, but an incubator of such diversity in turn.

In contrast to the grasping finality of “comprehensive,” “diverse” means “varied paths.” Collectors and propagators indeed take varied paths to find and grow trees for the collection—seeking seed at the top of a ridge and at its foot, taking cuttings from riverbanks and the arid edges of clearings,

Biodiversity
is liquid,
inventive,
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and ever on
the move.

at the peripheries of known ranges and deep within their forested hearts. Whether in suburban Ontario or on the slopes of Mt. Fuji, collectors note where a plant is growing, under what conditions of light, terrain, and proximity to other plants. These observations suggest where to plant in the Arboretum, how a given plant might respond to different conditions of soil, climate, light—how it might bump up against the edges of what’s known about the species. As well as determining what will thrive in our garden, this genetic diversity has implications for conservation and resilience in the face of climate change and habitat loss.

Working with collections can shed light on how biodiversity unfolds in the world beyond the garden’s edge. Botanist Jake Grossman, who studied the Arboretum’s maple collection as a postdoctoral Putnam Fellow, observes that the maples of North America diverge in crucial respects from their relatives in Asia, where the genus evolved some sixty million years ago. “After all,” he writes for *Silva* in 2019, “maple evolution has taken place over many extreme fluctuations in climate, the formation of the continents as we know them, and the coincidental evolution of diverse plant competitors, microbial symbionts, and animal pollinators and predators.”

Earlier, I called *Acer* a “middling taxon” when it comes to species count—but it turns out that diversity is more than an inventory. Biodiversity is liquid, inventive, ephemeral, and ever on the move. It’s not something that proceeds from a pure origin, nor does it point toward some final form or ultimate realization. It crops up at all scales, from the landscape to the individual leaf or flower. The collection varies continuously, and always offers the possibility of wonder. And thus a living collection is more than fixed and comprehensive—it is *diverse*. And this diversity is ongoing and ever unfolding. So, look up! 🌿

MATTHEW BATTLES is the editor of Arnoldia.

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The Ishikari River Valley in Japan's Minami Alps National Park, a crucial collecting site on the Arboretum's 2023 expedition. *Photograph by Michael S. Dosmann*

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Embedded specimen of *Hamamelis x intermedia* 'Arnold Promise'
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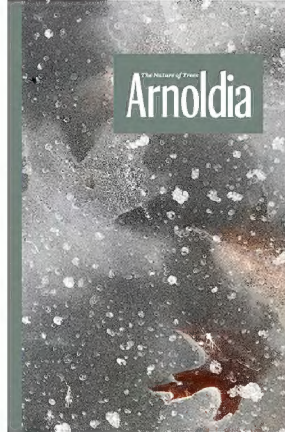
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LETTERS



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Sharing the balm of trees

Hello Matthew Battles from -18°F this morning in Big Timber, Montana—and it will be much colder tonight, but then, Boston is also experiencing challenging weather. So it goes, but winterscapes have their particular beauty along with other seasons, as eloquently said in “Balm for a World of Wounds” (*Arnoldia* 80:4). There is much I admire about your expressive writing. I walked and biked along with you throughout the Arboretum, despite 2,000 miles distance, in the pines, oaks, katsuras, redbuds and more. I also consider the 500-year-old West Bank olive trees and the malignancies you speak of.... Trees are truly for many of us the best known balm for peace and healing.

Additionally, I appreciate Rachel May writing about her experience and connection with McLean Hospital (“The White Oak Tree at McLean: a Case of Recovery”). My husband, Francis Blake (whose mother, Caroline Hunnewell Blake, had a strong family connection to Arnold Arboretum), and I were so appreciative of this issue of *Arnoldia* that we will be mailing our copy to an acquaintance who also loves and works with trees.

Sandi Blake
Blake Nursery
Big Timber, MT

Reading the landscape

Dear Editor,

Your magazine, *Arnoldia*, is a real gift. When I first became a member 23 years ago, I was pleasantly surprised to discover that I received a magazine along with the joy of exploring the landscape. When I'm in the landscape I don't think—I look, I walk, I absorb. In fact, there is so much in the landscape that in a way it is too much to think about each organism, so I let myself appreciate the whole impact. When I receive *Arnoldia*, that is when I get my pen out and make notes about things that I should remember and want to remember. That is when I experience the intellectual aspect of the landscape.

I think the fact that you have a palpable magazine, that we can touch and hold and

refer to quickly, to me, is immensely important. I also save articles so that they become part of my education and re-education. When I was housebound with cancer, for those moments I was reading the articles in *Arnoldia*, I could almost forget that I was a patient. And *Arnoldia* was a great reminder of what was waiting for me when I got better. That was an important message for my healing. I'm uplifted that my membership offers a way of supporting this great magazine. I truly believe that giving to this place as a member helps me enjoy this landscape so much more because it helps me belong to it!

Carl Scovel
minister emeritus
King's Chapel (Boston)

TREES OF LIFE

A Storied Forest

On the slopes of the Carpathian Mountains in Romania lies Nucșoara, a little town of 1,222 inhabitants, in a region known for such charismatic wildlife as brown bears and wolves. Importantly, the southern Carpathian Mountains are also home to two-thirds of Europe's remaining virgin forest, including a high concentration of beeches.

Recognizing that the forest was under threat from logging and bark beetles, Nucșoara's mayor, Ion Cojocaru, partnered with local nonprofits to create the Forest of Immortal Stories. 2,544 trees were photographed, mapped, and marked with a number plate. Now, the trees are available for adoption, and the adopter can attach their personal story to the trees. Such stories abound: in the not-so-distant past, villagers looked to the forest for firewood, food, and flowers. The trees will recite back these stories via QR code.

Speaking to *New York Times* journalist Alan Burdick, Cojocaru puts his own story simply: "the trees saved me," he says. Visit www.treeswithstories.com to learn more.



Notes from the Field



A Confounding *Crataegus*

An international team of plant explorers track down rare hawthorns thriving in the suburban wild.

A small natural area surrounded by restaurants and hospitals; behind a row of backyards in a suburb; next to hole five on a golf course—these are not locations generally considered when looking for rare trees. However, this is where our group found itself looking for a hawthorn in London, Ontario, Canada this past September.

Our species of focus was possibly one of the more cryptic taxa on the target list of the Arnold Arboretum's Campaign for Living Collections—a decade-long initiative to add nearly 400 taxa of high conservation, research, and horticultural value to the arboretum's living collections. True to a taxonomically complicated genus, *Crataegus perjucunda* (pearthorn or Middlesex frosted hawthorn) presents something of a mystery. Originally collected by D.W. Beadle in London, Ontario in 1903, and first described by Charles Sargent in a 1908 treatment,

"*Crataegus* in Southern Ontario," it is presumed to be endemic, and known only from a few voucher locations in Middlesex County, Ontario. The species received reinvigorated interest in the 1970s from James Phipps, an authority on the genus. Working with graduate student Quinn Sinnott, Phipps identified and collected voucher material in Ontario in 1977 as part of an analysis of *Crataegus* series *Pruinosae* in the region. Their research identified *C. perjucunda* as a distinctive entity, which, despite growing alongside other *Crataegus* species and thus theoretically subject to hybridization, reproduces "true to form." Currently, *Flora of North America* treats *C. perjucunda* within its closest congener, *C. cognata*, but as a "local species" chiefly differentiated by shorter, finer thorns and wider leaves. That it exists alongside multiple congeners but has remained readily distinctive over the

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decades suggests that it is a local apomict, reproducing from seed without fertilization. Its listing as “Critically Endangered” by NatureServe, and the need for germplasm to be included in collections for *ex-situ* conservation, prompted its inclusion in the Campaign for Living Collections list, and our subsequent quest to re-survey it.

In the summer of 2023, the Arboretum’s assistant curator, Miles Schwartz Sax, spearheaded an effort to re-survey Phipps and Sinnott’s 1977 herbarium voucher locations. An ambitious undertaking like the Campaign for Living Collections encourages people and institutions to pool expertise in the interest of plant conservation. Reflecting shared institutional interest in documenting the botanical biodiversity of Ontario as well as the genus *Crataegus*, our group came together from the Arnold Arboretum, the University of Toronto, the University of Guelph Arboretum, and Royal Botanical Gardens, Canada. We spent weeks communicating by email as we consulted herbarium specimens, acquired permits, set dates, and coordinated field supplies.

Armed with herbarium presses and pole pruners, we began our short trek away from the sounds of the city.

On a sunny Saturday morning at the end of September, the four of us met in a parking lot near the most promising set of coordinates to re-survey, in the Westminster Ponds Conservation Area, a roughly 200-hectare reserve established by the Upper Thames Conservation Authority and the City of London in the 1970s. Armed with herbarium presses and pole pruners, we began our short trek away from the sounds of the city and toward the spot where the species was last seen in 1977. We took in the unique ecology of the area, walking past kettle ponds—created from remnant ice blocks left by retreating glaciers thousands of years ago—and through low forests of red maple and bordering swamps. Nearing our first point west of Spettigues Pond, the upland forest composition offered a beautiful example of secondary succession, where thinning was creating gaps in an overstory rich with oaks, maples, beeches, and hop-hornbeams, providing resources for a burgeoning understory.

When we were nearly on top of our first coordinates, we found a *Crataegus*



SMALL WORLD

#plantblindness?

When scrolling through the emoji library on our phones, it feels like a never-ending supply. Who knew there was an hourglass emoji? A mousetrap, a ball of yarn, a troll—even a member of the King’s Guard! The list goes on. But have you ever considered how many nature-related emojis exist? A group of ecologists based in Italy recently investigated this question. “In our increasingly digitized society, we should not underestimate the potential of emojis to raise awareness and foster appreciation for the diversity of life on Earth,” they wrote. Using Emojipedia, the researchers found that of 112 total organism emojis, there were 92 animals, 16 plants, 1 fungus, and 1 microorganism. Animals were far overrepresented in comparison to plants, which aligns with current conversations around “plant blindness” and public prioritization of animal conservation. While overall emoji diversity has increased since 2015, there’s plenty of room for improvement—visit unicode.org/emoji/proposals.html to learn how to suggest botanical emojis.

immediately off the trail, tucked decidedly between canopy and understory. While this individual fit the distinguishing traits for the species, we decided to mark it and continue to scout for other congeners in the area. Hiking past a kettle pond and up a hill, we chose paths near the forest edge, looking for ideal hawthorn habitat. Sure enough, we soon saw another *Crataegus*, followed by another, and then three more. In true *Crataegus* form, all looked slightly distinct but not distinct enough to avoid confusion. While this presents an absolute dream for some botanists, it is a nightmare for others. After much measuring of thorns and leaves, consulting of keys, and discussing the details of *Crataegus* series *Pruinosae*, we returned to our original coordinates with greater confidence in our identification.

We took in the individual before us, right next to the edge of the trail. While unremarkable at first glance, it appeared to be quite old, with the slow, gnarled growth typical of *Crataegus* marking difficult growing conditions in dry Berrian sandy loam soils. The base of the trunk measured only 10.3 cm in diameter, the old gray-brown bark flaking off in irregular patches. It was extraordinary to think how many thousands of people had passed by it during the past half-century, not recognizing the special tree only a few feet away. We began to gather collection notes and herbarium vouchers, occasionally being passed by community members volunteering their Saturday to pick up trash throughout the natural area.

As we collected data and vouchers from our first specimen, we spotted another *Crataegus* that fit the description of our target—full of pinkish-red fruits, just six meters deeper into the forest. Although both trees looked like they could be over 50 years old, their canopies averaged out to just under four meters tall and wide. *Crataegus* taxonomy may be brutal, but lucky for us, their shorter height presents less of a challenge when sampling in the field (so long as you mind the thorns). We set to work with our pole pruners, collecting and counting seed carefully so as not to over collect and risk decimating the species we

Re-surveying and determining a species' absence provides critical information to calibrate future conservation efforts.

were there to preserve. Three branch samples were collected and field-pressed from each tree, with herbarium vouchers to be dried and frozen by staff at Royal Botanical Gardens, Canada. One voucher from each tree would be retained at the herbarium of Royal Botanical Gardens, Canada, with the other sets sent to the Arnold Arboretum, as well as the Royal Ontario Museum herbarium to reside along with those from the 1977 Phipps collection. Additionally, small lots of fruit were bagged for later processing and division between the Arnold Arboretum, the University of Guelph Arboretum, and Royal Botanical Gardens, Canada, with the goal of including this species in the living collections of these organizations.

Following our successful collection at Westminster Ponds and still riding the high of fieldwork, Jon Peter mentioned that he had contacted the golf course where one of our remaining coordinates was located—squarely on the green of hole five. While the tree was unlikely to be present at that exact location, hole five bordered on a large expanse of forest leading down to the Thames River. Deciding it was worth a look, we met with an employee at the pro shop, who, intrigued by our story, chaperoned us via club car to our coordinates. After waiting for play to end, we trampled through the overgrown wood's edge in our dirty field gear, catching a few bemused looks from club members rolling by in carts and starched shirts. In the edge habitat between the course and deep woods we spotted a lone *Crataegus*—but not our target species. A similar search ten minutes away, at a set of coordinates next to a ravine in a recently built suburban development, also turned up dry.

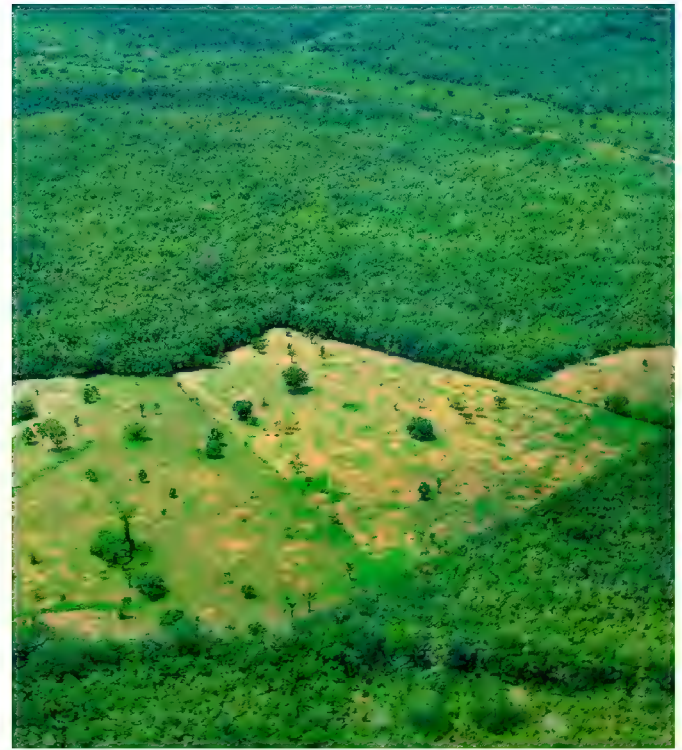


Although unsuccessful at the golf course and in the depths of suburbia, we had been able to re-survey three of Phipps' and Sinnott's original 1977 collection locations, including Westminster Ponds. While one out of three may not seem like a great result, re-surveying and determining a species' absence provides critical information to calibrate future conservation efforts.

The importance of time spent in the field may be measured most readily in physical results like herbarium vouchers and seeds. Less tangible but equally important is the activation (or reactivation) of threads between plant research, conservation, and horticultural institutions to continue conservation efforts. Beyond sharing vouchers and germplasm, ideas are generated, information is disseminated, and the network of people focused on a species is continually widened.

Trips such as this also bring to our attention the importance of urban conservation areas—even small ones—as critical refugia. London is one of Canada's fastest growing metropolitan areas and lies within the most species-rich region in the country. A small city of 125,000 in 1950, over the past 70 years the population of London, like many other cities its size across North America, exploded to over 422,000 by 2021.

With ever-expanding urban development, protection of lands like the Westminster Ponds Conservation area is of the utmost importance, not just for the multitude of benefits to humans, but for the many species that rely on these relict refugia in now highly developed spaces. *Crataegus*, just one of hundreds of plant genera that call southern Ontario home, provides food and shelter for many species of birds and mammals. Hawthorn flowers provide food for nectar-feeding insects, and the trees serve as important host plants for over 130 species of caterpillars, making *Crataegus* a critical, keystone genus in eastern temperate forests. While its taxonomy may often be cryptic and confounding, this diversity is critical to us and the many other species that rely on it, and it is well worth the challenge to conserve. 🌿



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OUR WARMING WORLD

Taking a Cut

Tropical rainforests are some of the most biodiverse ecosystems on the planet—not to mention all the ways they help to cool the climate. And yet every five seconds, a soccer field-sized area of mature tropical forest is burned or cut to make space for crops and cattle, according to the World Resource Institute. Taking steps toward reforestation is vital, but how can landholders be incentivized to plant trees and protect the existing forest? New research has uncovered a simple answer: for reforestation projects to be successful, they must “work with and for the people who live there.” Researchers from the Smithsonian Tropical Research Institute's Agua Salud site in Panama found that allowing landholders to generate revenue from their land incentivizes them to care for and protect the forests. This can be done by paying landholders to plant and care for trees while simultaneously allowing them to harvest selectively and sell their timber. Although cutting trees may seem counterproductive, reliable payments to landholders can lead to both thriving forests as well as financial security for the area's landholders.



In and Out of Ancients

Dan Crowley explores the ancient yews of Herefordshire, whose hollows have seen friends, fire, and the long expanse of time.

Dan Crowley is a dendrologist and is tree conservation manager at Westonbirt, The National Arboretum, UK. As well as his role at Westonbirt, he enjoys documenting trees in the UK and beyond. He posts on Instagram @thetreespotter.

Though my home county of Gloucestershire is rightly renowned for its exceptional trees, I often head a little further west to Herefordshire, hotbed of ancient trees, in search of new (to me!) and exciting arborescent treasures. Having read about the Linton Yew—a churchyard specimen once estimated to be an incredible four thousand years old—I decided it was a tree I couldn't not meet.

En route to Linton I had made a pilgrimage to a favorite tree, another famous yew at Much Marcle. This tree, likewise an ancient (and hollow) churchyard yew (*Taxus baccata*), has the unusual distinction of having a bench inside it. I gather that it makes for a popular spot for wedding photos for couples who have just tied the knot in the

church, though the tree long pre-dates the church by which it stands.

The sun was out when I arrived at Linton—a welcome sight and a break from the near-incessant rain of the previous few weeks. The church stands more or less at the center of its tiny village (aside from the church and a pub, there isn't a whole lot more there), both church and churchyard sitting at a somewhat elevated position, with a handful of steps leading up from the roadside to the entrance of the churchyard.

As I walked up the steps, the scale of the Linton Yew quickly became apparent, its dark crown dominating a large part of the churchyard, obscuring much of the church itself. Though its trunk is not quite entire, it is massive, with a prominent bulge less

than a meter off the ground. I had read that it had been previously measured at nearly ten meters (!) in circumference. A semi-circle of evenly spaced, painted stones follow the shape of the tree's trunk part way across the path, acting as a buffer between path and tree.

Coming up alongside the tree, I could see a huge V-shaped opening facing the path, revealing the large extent to which the trunk is hollow. Like the Much Marcle yew, it would be quite easy to step right inside the tree's hollow bole—though here that sort of action is evidently viewed as an intrusion. Accompanying the painted stones is a sign, printed on laminated paper and pinned to a wooden stake propped against the tree, the base of which extends through a hole in the stem. It reads “KEEP OUT... Please help protect this ancient tree by not entering its hollow trunk,” and includes a note that the tree is “lovingly maintained” by a local arboricultural company.

I then noticed what is presumably the primary reason that the sign and stones have been put in place: much of the inside of the trunk was charred, with large, blackened areas evident on all sides. Clearly the tree had been the victim of a significant fire at some point in its not-too-distant past.

Moving around the tree, I could see that on its southern side, closest to the church, a wooden prop had been installed, put in place to bear the weight of branches overhanging the path around the church. I also noticed the odd fruit: evidence that the Linton Yew is female. Inside the original trunk of the tree grows a “new” stem a foot or so in diameter. Seemingly derived from an adventitious root, it makes for a fine exhibit of why yews are so apt to regenerate.

Finding myself almost at the entrance to the church, I wandered into the porch, pondering that there might be some information on the tree there. Scanning the noticeboard, I saw—alongside the listing of the altar-flower rota and calendar of services—a two-page piece on the tree, including black and white images of the tree “today” and in 1909, though details in the latter were hard to make out. According to

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the church's information, the age estimate of four thousand years was printed on a certificate awarded to the church by the Conservation Foundation, an age that would make the tree the oldest yew in England. However, recent estimates are more conservative at around 1,500 years old, though its giant girth renders the Linton Yew the largest yew by circumference in the country, and the UK Tree Register and Ancient Yew Group both believe it could be the oldest as well. Hollow trunks and an ability to continually regenerate make yew trees notoriously difficult to age! The article did state with certainty when the tree was set on fire, though—nearly catastrophically, in 1998.

Though only a single tree goes by the name of the Linton Yew, it is not the only yew in Linton churchyard. Experience has taught me that where there is one good tree, there's often another (or more). And churchyards often tend to throw up one or two surprises.

With that in mind, I made my way around the church building, passing a few specimens of Irish yew (*Taxus baccata* ‘Fastigiata’), before being faced with another impressive specimen! Though not of the same dimensions as the tree out front, it was definitely ancient, with another largely hollow trunk supporting a good, rounded crown. It too was entirely open on one side, the gap proportionately narrower. I wondered if this tree was an offspring of the Linton Yew. Surely feasible, but what struck me most about this specimen was its bark, which was far more textured than that of its presumed parent, exfoliating in small flakes.

As I stood by the second Linton yew, a maintenance contractor came around from the front of the church to tend a grave to the east of the churchyard. I continued to marvel at this taxaceous beauty a while longer, though when he fired up the strimmer to cut some grass, I decided it was time to leave. I wandered back around the front of the church the way I came and out down the path, pausing briefly once more at the Linton Yew before heading on my way, as the skies clouded over once again. 🌿



Beauty in a Dry Season

Christina Varnava learns that it takes persistence, directness, and optimism to communicate sustainability in a land of abundance.

Christina Varnava is the Living Collections Curator at Santa Barbara Botanic Garden, where she manages nearly a century of plant records. She loves the plants and wild landscapes of California.

I was walking through our collections at Santa Barbara Botanic Gardens one day in early December—it was 68 degrees, a sunny day. One of our gardeners flagged me down accompanied by a visitor who had a question about our meadow, which is filled with native grasses and forbs. In springtime the meadow is an explosion of California poppies (*Eschscholzia californica*), but in the heat of a dry December, it's mostly dominated by purple needlegrass (*Stipa speciosa*).

The visitor—a hip-looking woman with dyed magenta hair and fashionable sunglasses—got straight to the point. She wanted to know why our meadow looked so dull. She asked why we didn't just add

more flowers to keep it blooming all year. It's not an uncommon question—folks here in southern California are used to seeing the year-round abundance of tropical ornamental plants. California has been idolized as a land of boundless resources for nearly 200 years. We are beginning to understand the true ramifications of this belief as water tables lower and we buckle under drought conditions and record heat waves. Part of my role as an advocate for native plants and habitats is pushing back against this false narrative. I believe it is vital to educate people about the unusual Mediterranean climate that shapes the plant life here in California: hot, dry summers and cool (hopefully wet) winters. Plants in California experience drought conditions for months at a time, during the hottest months of the year. Most native plants are adapted to this cycle, but the tropical plants and lush lawns we're used to seeing require additional water to survive.

With all of this knowledge at my command, I felt well-equipped to answer this pointed question from our visitor. I replied that most California native plants are dormant this time of year, especially the showy annuals. I explained that we were currently in the dry season, and that while most plants were waiting for rain, other plants in the garden were having their moment.

This visitor, however, was persistent, and she was not satisfied with my answer. She responded that it was a shame to waste such a great space with abundant sun on such a drab display. It's hard to blame her for thinking this way, when gardeners in southern California have long celebrated the ability to plant anything and everything. Our mild winters allow for ornamental plants from around the world to be cultivated here—they just need plenty of water to get through the summer. For an example close to home: massive ornamental banana plants, roses, ivy, cacti, bluegrass, boxwood, yucca, and star pine all grow in the courtyard of my apartment complex—where the sprinklers run every night. And that's the key point. This apparent abundance comes at a cost, and we don't, in

fact, have unlimited resources. California has declared a drought-related state of emergency twice this century, during the drought from 2007–2009 and again from 2012–2016. No one is certain how the changing climate will impact the drought cycles in the southwest, but it seems prudent to prepare for further droughts.

To our visitor I explained that for plants in California, late fall is the equivalent of winter for plants in other parts of the country. Plants here struggle the most during this time of the year, when they have been waiting for water all summer. Our spectacular superblooms are built on this cycle of drought and rain, and they are not something that plants can support year-round. Ultimately, water is the limiting factor for them, and for us. We also try to garden sustainably and use minimal water. The fact that the meadow is located in a warm, sunny area provides difficulties for the plants in its own way. While it stands in opposition to how most people are used to thinking about plant stress, it is part of our unique climate.

Our guest countered my statement, noting that we had gotten a lot of rain since last year. The lakes and reservoirs were all full again, so shouldn't a lack of water no longer be a problem? I tried to explain that one rainy winter was not enough for the long term, that our groundwater was still depleted, that we still desperately need to see water as a precious resource.

She shook her head, and pointed out that if the cut-flower fields in Lompoc could do it, so could we. She ultimately did not seem swayed by anything I said, and she walked away shortly after. I keep thinking about how we are trying to turn back the clock on a very old narrative. We are trying to combat the anthropogenic view that the world is full of resources to extract for humanity's benefit, and it will not be easy to change this attitude.

I struggled after this interaction to think of anything else I could have said to be more compelling, or more persuasive. Day to day, I usually interact with people who understand my passion and my commitment to protecting California's wild plants and

WELL SAID

"As trees begin to wake this spring, let the blooming flowers remind you of the months of rest that made them possible."

Christina Janulis in "Fruitless Springs: Waking from Dormancy in the Anthropocene," page 62.

places. This interaction was an important reminder that there are still many people who think of water as just another resource for humans to use. Many don't yet understand the value of water simply accumulating in the ground, but I hope that someday they will. That's why I keep practicing scientific communication. That's why I keep writing, reading, and advocating. That's why I keep adding plants to our collection, and why I keep sharing their stories. We can't just get through to the people that already buy in. So, I am prepared to stay put through the difficult conversations and face each one with optimism. 🌿

Stachyurus praecox

By Scott Phillips

My favorite moments as a horticulturist occur when the beauty of nature moves me in a spiritual way, inspiring feelings of awe, serenity, joy, and profound peace. I consider myself blessed to work at the Arboretum, which offers us countless ways to experience these connections throughout the fleeting seasons. In summer, I love witnessing grasses dancing in the wind while holding the light of the sun, while in winter stands of towering conifers hold snow after a storm. I feel this connection while observing the majesty of the oak collection in the fall, and when seeing the first spring flowers after the long dormancy of winter.

Among my favorite spring flowers is the often-overlooked *Stachyurus praecox*. I remember meeting this plant while working as a gardener in the Morris Arboretum's Camellia Collection. Stumbling upon it, I was immediately moved by the long tails of yellow bell-shaped flowers that loaded every branch and node. It was like finding an elegant and ethereal upside-down chandelier, a plant springing from the earth as if in celebration of life itself.

A deciduous understory shrub, *Stachyurus praecox* is a perfect plant for shade gardens and edges. It flowers on old wood before the leaves fully emerge, granting an enchanting and long-lasting display in early spring—*praecox* meaning “very early” in Latin. Although there are only ten or so species in the genus *Stachyurus*, all share similarly intense ornamental flowering qualities. The most cultivated include *Stachyurus praecox*, *S. salicifolius*, and *S. chinensis*. All are native to East Asia, where they thrive in the mountainous regions of Japan, China, and the Korean peninsula.

Usually beginning late March and early April, the Arboretum's *Stachyurus* will once again wake up and sparkle to stardom in our landscape. The most prolific display at the Arboretum is *Stachyurus praecox* (1428-83*B) located on the south side of the Hunnewell Visitor Center. For those interested in stumbling upon the flowers the way I did, I encourage a visit to the Explorers Garden, where multiple plants grow throughout the collection. I hope this inspires you to marvel at their hypnotic chandelier-like flowers that light up the landscape and remind us that the world is still a wondrous place. And on a good day, if you look long enough, you may see their flowers as beacons signaling the death and rebirth of life on earth, a connection which unites us all. 🌿

Scott Phillips is the assistant manager of horticulture at the Arnold Arboretum.

Cascading flowers of 75-90*A in the Explorers Garden, March 2023.
Photograph by Kyle Port





FIELD AND FOREST

Science and Spirit in the Forests of Central Honshu

By Miles Schwartz Sax

After a three-year hiatus, the Arnold Arboretum resumed its international plant exploration work in fall 2023. Keeper of Living Collections Michael Dosmann and Assistant Curator Miles Schwartz Sax (author of this article) undertook a sixteen-day expedition (September 15–October 1) to Japan, where they traveled through central Honshu and the southern island of Kyushu in pursuit of acquiring seeds and herbarium vouchers of target woody plant species. We traveled in support of the Campaign for Living Collections, which is the Arnold Arboretum's signature plant-exploration and collection-development initiative. The Campaign was launched in 2015 with the goal of acquiring 395 woody plant taxa from across temperate

Mount Fuji's mist enfolds a forest of *Stewartia serrata*, a species that has proven elusive for the Arboretum to grow. Photograph by Miles Schwartz Sax





AVENUE OF CRYPTOMERIAS AT NIKKO.

A Brief History of the Arnold Arboretum in Japan

The floristic diversity of Japan has long been important to plant collections of the Arnold Arboretum and Harvard’s botany programs at large. Asa Gray (1810–1888), Professor of Botany at Harvard, drew early and influential parallels between the floras of Japan and Eastern North America, examining thousands of herbarium specimens collected by Charles Wright in Japan between 1853 to 1856. This work laid the foundation for Gray’s “disjunction thesis,” with a landmark publication on the subject in 1859. Armed with Gray’s thesis, the Arnold Arboretum’s first director, Charles Sprague Sargent, aimed to test the viability of Japanese plant species in his nascent Arboretum. In 1876, Sargent enlisted the help of William S. Clark to collect seeds and herbarium vouchers while serving as the first president of Sapporo Agriculture College (now Hokkaido University). Clark’s most significant introduction was the Japanese tree lilac (*Syringa reticulata*), thought to be the first introduction of the species into North America. One of Clark’s original collections of *S. reticulata* (1111*A) still stands 148 years later, one of the oldest cultivated trees in the Arboretum. For Sargent, these acquisitions provided proof that Japanese plant material would be well-matched to Boston’s climate. In 1892, Sargent had the opportunity to visit and experience the flora firsthand, acquiring some 200 seed collections and 1,225 herbarium vouchers—but perhaps more importantly, he was convinced of the botanical and horticultural merit of plant exploration in East Asia.

The Arboretum has been to Japan eleven times, collecting both wild species and significant cultigens, tapping into the diversity of Japan’s deep horticultural traditions. The initial era of plant exploration in Japan included five trips between 1892 and 1919 conducted by Charles Sprague Sargent, Ernest Henry Wilson, and John George Jack. The second period started in 1969 with a trip by Shiu-Ying Hu, and continued in 1977 with Steve Spongberg and Richard Weaver’s visit. Hu focused on taxonomic research, undertaking fieldwork in Kyushu and visiting herbaria, botanic gardens, and universities in Osaka, Kyoto, and Tokyo. Spongberg and Weaver’s 43-day trip to Japan and South Korea centered on plant exploration and reestablishing an institutional focus on conservation and floristic studies in the two countries. The third period started in 2018 and continues today, focusing on acquiring taxa for the Campaign for Living Collections and developing research partnerships.

regions of the world. Germplasm acquired throughout the Campaign prioritizes species of conservation concern and focuses on expanding phylogenetic and biological breadth of the living collections. Historical institutional focuses such as acquiring North American and East Asia disjunct species and marginally hardy taxa have also been prioritized. The Campaign represents the Arboretum's most targeted and ambitious plant acquisition program to date and offers a unique model for collections development (Friedman et al., 2016).

As of the start of 2024, the Arboretum has undertaken twenty-six expeditions across North America, East Asia, and Eastern Europe under the Campaign's banner. The 2023 expedition to Japan marks the fourth trip to the country since 2018, leaving sixteen taxa to acquire out of the original sixty-four that were included in the Campaign's desiderata (wish list). It was also the eleventh trip since the Arboretum's first Director, Charles Sprague Sargent, first visited in 1892. Our approach to plant acquisition has changed a great deal over the intervening years, along with our understanding of plant and community ecology.

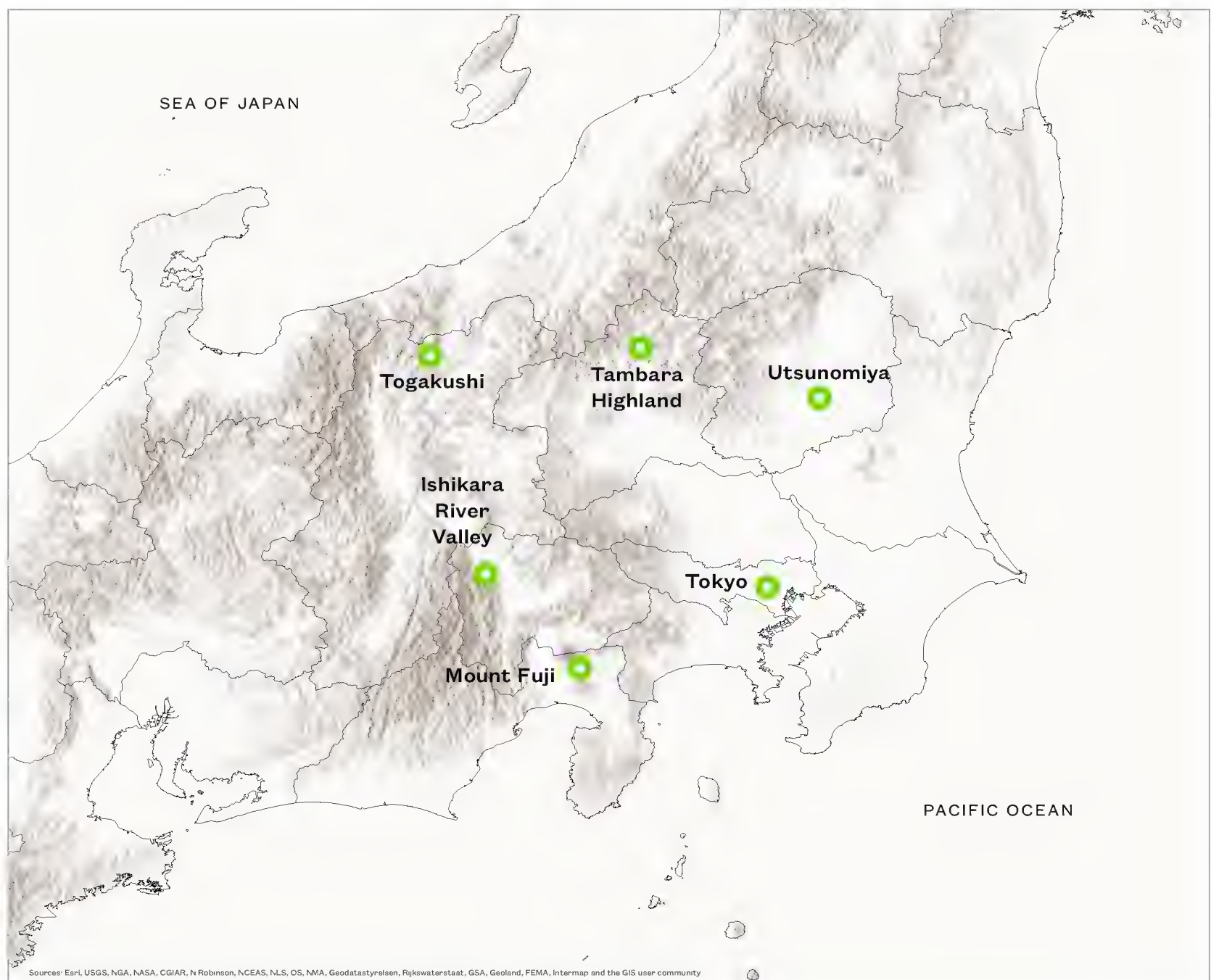
An Ecological Approach to Plant Collecting in Japan

While early plant explorers were focused on collecting broadly to support descriptive taxonomy and horticultural novelty, our collecting strategy has evolved more nuance. As we acquire plant material aligned with the goals of the Campaign for Living Collections, we also gather a complementary suite of data. This includes information like location information (GPS points, country, city, province/state), data about the environment (altitude, habitat, slope, aspect, soil type), observations on the individual plant, their floristic community, and photographs. These data paint a picture of the ecology and site preferences for plants we are acquiring. The environmental information for the site is critical in helping to make decisions on how to cultivate the plants once we are growing them within the living collections back in the Arboretum. Locality information will facilitate future recollecting efforts, and allows us to share the locations for individual species with the broader botanical research community.

The distribution of individual plant species reflects their preference to grow within specific ranges of environmental conditions such as elevation, rainfall, minimum or maximum temperatures, and latitudes. To grow successfully outside of its native

range, a plant species requires either an analogous environment or tolerance to a variety of climatic and edaphic factors. Japan features a range of climates from the subtropical islands of Okinawa to cold temperate island of Hokkaido and span a latitude roughly equivalent to the distance from Maine to Florida of the USA eastern seaboard. Part of the reason that so many Japanese plants have a significant presence in the cultivated flora of the US is because of the high proportion of analogous environments between the two countries. Japan has circa 5,500 indigenous plant species growing on the country's 377,975 square-kilometer land mass, compared to North America's circa 18,000 plants species growing on 24.6 million square kilometers. Stated another way, Japan contains the equivalent of 31 percent of the flora of North America on two percent of the land mass.

The central island of Honshu was one of the two primary collecting locations for the 2023 expedition. In Honshu, among the most significant ecological drivers are the effects of the Sea of Japan and the Pacific Ocean. Honshu, Japan's largest island, extends in a generally northeast to southwest orientation over the length of 1931 kilometers (1,200 miles). In the summertime, the Pacific Ocean generates warm air masses and creates associated rains and typhoons. In contrast, the Sea of Japan develops monsoons in the winter months, bringing heavy snow and precipitation to Northern Honshu and Hokkaido. The spine of mountains running the length of Honshu acts as barrier for precipitation, reducing the amount of this moisture reaching the Pacific side of the island in the winter. As a result, snowfall on the Sea of Japan side tends to cover the mountains for periods of three to five months, providing consistent moisture to seedlings in the spring, insulating the soil from freezing temperature, and reducing seed herbivory compared to the Pacific Ocean side. Along with topography, these contrasting patterns of summer or winter precipitation play a significant role in individual plant species distribution and associated floristic communities (Hara, 2023). Therefore, many Japanese plant species are delineated as occurring on either the Sea of Japan or the Pacific Ocean side of Honshu. For example, the Japanese beech tree, *Fagus crenata*, is primarily found on the Sea of Japan side in regions within heavy snowfall areas. On the Pacific side, its distribution is patchier, often limited to higher elevations. This contrasts with *Fagus japonica*, which is primarily found across the Pacific side of Honshu. For species that have wide ranges, some



The 2023 expedition ranged through many prefectures across central Honshu, Japan's largest island, from the Pacific Ocean to the Sea of Japan. *Map by Kyle Port*

studies have shown adaptive morphologies to either the Pacific or Sea of Japan in response to environmental pressures, which are sometimes distinctive enough to assign subspecies classification based on their phenotypes and supportive phylogenetic trees.

The Journey Begins

After arriving in Tokyo September 17th, we took the Shinkansen high speed rail to the city of Utsunomiya which would be our base of operations while collecting in Japan. Utsunomiya lies within the northern reaches of the Kanto Plains, a vast lowland area of some 17,000 square kilometers that extends over Tokyo and six prefectures in Eastern Central Honshu. Defined by the Pacific Ocean to the east and mountainous regions to the west and north, the Kanto is the largest plain in Japan. From the mountains, a series of associated river systems drain from the highlands, transversing the plains and extending to the Pacific

Ocean. The Kanto Plain is a patchwork of developed towns, cities, and a mixture of industrial landscapes and agricultural fields.

On September 18th we met our host, Dr. Mineaki Aizawa, and his undergraduate student Yoshinari Hata. An associate professor of forest ecology and silviculture at Utsunomiya University, Mineaki has been our primary collaborator during work in Japan since 2018. This collecting expedition marks the fourth trip that Mineaki has collaborated with the Arnold Arboretum since the start of The Campaign. He has been an extraordinary partner helping to secure collecting permits, access sites, and navigate Japan's physical and cultural landscapes. Mineaki is an excellent field botanist, having studied forest ecosystems and species diversity across the country, making him an indispensable asset and patient teacher in the field. His research interests span from the ecological to the historical—at times blending



The summit of Mount Amagabara in the Tambara Highlands where *Eubotroides grayana* was founding growing along the exposed slope. Photograph by Michael S. Dosmann

the two together. Between 2007 and 2015, Mineaki and his colleague, Tatsuhiro Ohkubo, followed archival photos taken in Japan's Nikko region by Arnold Arboretum staff members Ernest Henry Wilson and John George Jack in the early 1900s. They retraced the steps of Wilson and Jack, locating and re-photographing many of the same trees over a hundred years later (Aizawa & Ohkubo, 2016).

After assembling at the train station, our team drove west toward the Tambara Highlands in Gunma prefecture, crossing the Kanto Plain and climbing winding roads that followed the Hotchi River Valley into the mountains. As we ascended above the lowlands and agricultural fields, we began to pass small plantations of Japanese cryptomeria (*Cryptomeria japonica*), also known as sugi, cropping up along the hillsides bordering the road. Sugi is the most commonly cultivated forestry tree in Japan, so these plantations would soon become a familiar

sight. As we climbed the mountain, the forest flora started to become more varied, with a mix of deciduous species such as Japanese wingnuts (*Pterocarya rhoifolia*) and horse chestnut (*Aesculus turbinata*). After a series of circuitous switchbacks, the road straightened out, and we caught glimpses of Tahamata Lake, a human-made reservoir perched in the mountains of the Kamihotchimachi region. We parked the car at the end of the public access road at a visitor center for the nature preserve, gathered our variable collecting supplies, and donned backpacks. The plan was to ascend Mount Amagabara, topping out at 1450 meters (4760 feet), and see what plants we found along the way.

Getting out into the forest, we started to get a feel for the vegetation of the region. The characters of diverse maple species greeted us from the trailside, such as the elongated petiole of *Acer nipponicum*, the familiar lobed leaves of *Acer palmatum*, and

the brown tufted abaxial surfaces of *Acer rufinerve*. Climbing throughout the taller trees in the forest, *Hydrangea anomala* subsp. *petiolaris*, a climbing hydrangea, snaked its way high into the canopy. *Cornus controversa*, though still an understory tree in these forests, seemed a giant compared to its more diminutive North American cousin, *Cornus alternifolia*. *Tilia japonica* was easy to point out with its characteristic asymmetrical cordate leaves, but the subtle ornamental character of its bark left a deep impression, reminding me more of katsura (*Cercidiphyllum japonicum*) than basswood. While Tambara Highland provided habitat for a great diversity of plant forest taxa, the predominate tree species were the Japanese beech (*Fagus crenata*) and associated understory of waist high broadleaf bamboo (*Sasa kurilensis*).

Our path eventually led us to the ridge line leading up to the summit of Mount Amagabara. Close to the top, the forest gave way to an opening. Along the ridgeline, a landslide had removed the trees and exposed an open slope. This gave spectacular views down to Lake Tamahara and the surrounding mountains. Succession was taking its course along the slope, and the landscape was filling with a dominant shrub layer. To our great excitement, we spotted our first target for the day, *Eubotroides grayana*, a shrub member of the heath family (Ericaceae) that is sometimes lumped with the genus *Leucothoe*. We excitedly made our first collection of the trip, gathering seeds and falling into our collecting roles, the designation of which fell to each party member through a combination of intuition and assignment. Mineaki was our de-facto expedition leader due to his planning of the trip and familiarity with the local flora and landscape. Michael, with his keen eye for observation and meticulous attention to detail, was the recorder, keeping both a journal of the trip and collecting notes for individual acquisitions. With his sharp eyesight and proclivity for adventure, Hata was our scout, willing to scramble over streams and complicated terrain and ensured we found every possible seed in a population of plants. I took on the role of herbarium collector, ensuring we captured representative vouchers with diagnostic features like flowers in anthesis or dehiscent fruits for each collection. Role assignment helps to make the collecting process run smoothly and ensures that nothing is missed in the collecting process.

After making our collection, we headed back down the mountain, surprised to find *Mitchella undulata*, a member of the Rubiaceae, creeping throughout

the bamboo. The genus *Mitchella* is a classic North American-East Asian disjunct, with *M. undulata* occurring in Japan and *M. repens* in the Eastern USA, Canada, and Mexico. *Mitchella undulata* has undulating leaf margins and red fruits, and although it is difficult to locate, we were eventually successful in finding a handful. We experienced many other botanical sights over the course of the day, such as stands of the *Clethra barbinervis* with its attractive modeled bark, mature stands of *Thujopsis dolabrata*, and the occasional *Magnolia salicifolia* with its characteristic grape-scented leaves. Along this path we also encountered the two lone leaves of a tiny *Virbunum urceolatum* plant—a rare, elusive species about which little is known in the world of the viburnums. This species is a collecting target, but unfortunately, no fruits could be found on the diminutive plant.

The trail eventually led us to an open wet meadow close to where we started the day. This area had a boardwalk for easy access, and there we encountered a second population of *Eubotroides grayana*. This time it was growing in moist lowland soil, a large contrast to the dry, slope-side habitat we had seen it in a few hours before. We made a second collection of the *E. grayana*, and before the day was done had additionally acquired *Weigela hortensis* growing on a wet road cut along with *Acer nipponicum*.

Togakushi Forest Botanical Garden

The next day (September 19th) we ventured south to our next collecting location, in Nagano Prefecture: Togakushi Forest Botanical Garden, a 71.34-hectare (173 acre) conservation area within the boundaries of the Myoko-Togakushi Renzan National Park. That national park comprises 39,772 hectares (98,280 acres) in a mountainous region featuring seven peaks taller than 1,900 meters (6233 feet). This region features weather patterns characteristic of the Sea of Japan, with high volumes of winter snow and moderate summer temperatures. Togakushi Forest Botanical Garden was established in 1963, commemorating the 15th National Land Greening Convention and National Tree Planting Festival. While the name “garden” suggests a cultivated landscape, in reality it is a conserved forest that also features a nature center and interpretive displays.

The Forest Garden featured a series of trails and boardwalks, which made for easy walking as we moved into the forest. The trail initially ran along a gentle hillside, passing under a canopy of even-aged Japanese larch (*Larix kaempferi*) indicating a historic

As shrine forests have grown old, these landscapes have come to provide added benefits.

timber plantation. While Japan is a country densely covered in dominant native forest ecosystems, it is also heavily influenced by a history of timber management. Plantations of larch, hinoki (*Chamaecyparis obtusa*), and sugi were common occurrences almost everywhere we visited. The larch and *Sasa* decreased as we walked downhill over a stream and into the flood plain, which opened up with a greater diversity of plant species. This lowland forest had a mature canopy of *Ulmus davidii* var. *japonicum* with a rich mixture of smaller trees and understory shrubs. The forest floor was filled *Pachysandra terminalis* happily growing in dense shade and forming a dominant ground cover, sporting a handful of ghostly white fruit. In close proximity to the stream, we were treated with the blooms of bottlebrush *Actaea simplex* with its exclaiming inflorescences punctuating the course of the slow-moving water.

Here we found one of our targets for the day: *Viburnum sieboldii* var. *obovatifolium*. This species is generally known in cultivation for being a larger viburnum with the capacity to grow into a tree up to eight meters (26 feet) tall. This variety of the species, however, found in the Sea of Japan-side flora, is noted as only reaching a maximal height of around two

meters (six feet), with larger leaves than the straight species found in the Pacific flora. Collections of the viburnum were made before venturing further into the lowland forest, where we collected a second target shrub for the day, *Viburnum plicatum* var. *tomentosum*. A third viburnum species, *V. opulus*, was noted in the area along with *Ilex crenata*, *Pyrus ussuriensis* var. *hondoensis*, and an unidentified *Paeonia* sp.

While the shrub taxa were exciting to encounter, the real prize for the day was finding the tree lilac, *Syringa reticulata* var. *reticulata*, which we first came across in the parking lot as a single specimen. While not as romantic as finding the species secluded deep in the forest, we made collections here, hoping we would come across more along the way. In the same lowland habitat as the viburnum, we had success finding a towering old lilac tree that was at least seven meters (22 feet) tall and with a spread of four meters (13 feet). The lilac tree was happily growing in partial shade under a canopy of elm, with a multi-stem form. Although not as striking as single-leader trees I've seen in cultivation, the height of this tree alone was impressive. It delighted the mind thinking about how an open-grown seedling from this collection might respond in the Arboretum with a few decades of growth under its belt. What also struck me about collecting this individual was the fact that it grew in flood-plain habitat. Tree lilac is a popular ornamental in cultivation in the US, and it is common to find it planted in sidewalk tree pits in marginal urbanized soils. Seeing this individual growing in seasonally wet flood plain suggests tolerance to variable soil moistures, expanding our understanding of the species' site preferences.

After spending the morning collecting at the Forest Botanical Garden, we headed to the adjacent land of the Togakushi Shrine. The original structures on the site date to the middle ninth century, but the shrine rose to prominence in the Kamakura period (1185–1333 CE), when Mount Togakushi was recognized as a leading sacred peak in Japan (Kimura et al. 2013). While the shrine itself draws visitors, so does a magnificent 400-year-old, 500-meter (1640 ft) long allée of sugi trees (*Cryptomeria japonica*). With the sugi laid out as an allée, they create the sensation of entering a towering arboreal cathedral. Visitors appear miniature in contrast to these forest giants soaring some 35+ meters (115 ft) above the forest floor. These types of sugi plantations or “shrine forests” were thought originally to have been planted as future timber resources to rebuild shrine structures



An allée of 400-year-old sugi (*Cryptomeria japonica*) at the Togakushi Shrine exerts a sublime presence. *Photograph by Miles Schwartz Sax*

in their eventual decline or in some cases as a natural resource to support the needs of the local community. The surrounding forest had been influenced by the de-facto land conservation, preserving habitat and fostering the growth of immense *Aesculus turbinata* and *Quercus mongolica*.

Over the decades and centuries as shrine forests have grown old, these landscapes have come to provide added benefits, including wildlife habitat, creation of microclimates, and green space in urban environments. They have also come to be seen as symbolic forests that are expressions of Japanese traditions and culture (Kimura et al., 2013). Walking up the Togakushi Shrine path between the trunks of 400-year-old sugi is a grounding experience. Standing next to such old organisms brings an inner calm and induces reverence. The linear layout of the sugi allée speaks to something in the human spirit, a co-creation born of human imagination and expressed through deep time and arboreal beauty.

While these forests give the impression of a wild landscape, they were established by horticultural practice hundreds of years ago, and are not strictly self-regulating like a natural forest. As a result, they require human intervention, such as planting new trees or protecting root zones to keep these forests intact and aligned with the cultural and ecosystem services they have come to provide. Given the ability to track these shrine forests from their origins, research groups have studied these ecosystems using population genetics and forest-dynamic techniques (Kimura et al. 2013). Their findings help to shape the understanding of these anthropogenic ecosystems and ensure they continue to provide both ecological and anthropological benefits. The experience of visiting the Togakushi Forest Botanic Garden and comparing its forest with modern plantations made for a fascinating contrast in forest management from two historical periods. It makes me wonder if any of the trees we are collecting on this expedition will be at the Arnold Arboretum in the year 2423. One can only hope that one of our collections someday will elicit similar feelings to standing under the boughs of sugi planted in the seventeenth century.

Ishikara River Valley

Leaving Togakushi on September 21st, we headed south out of Myoko-Togakushi Renzan National Park, traveling through the agriculturally rich river basins of central Nagano prefecture. After spending a night in the city of Suwa, we crossed over into

Yamanashi Prefecture, where we started to see elements of the Pacific flora like Japanese walnut (*Juglans ailantifolia*) and chestnut (*Castanea crenata*). Our collecting destination for the day was the Ishikari River, located on the northeastern slopes of Minami Alps National Park. We drove up winding roads that passed through low-elevation sugi plantations. As we crossed over the boundary line of the national park, we found ourselves driving through rich stands of native deciduous forests. Upon reaching the parking lot, we packed our field bags, donned leech socks, and headed off along a hiking trail that traces the Ishikara river. We immediately noted the diversity of tree species that surrounded us. The site was particularly rich in maples, offering an opportunity to compare the morphologies of species such as *Acer cissifolium*, *Acer maximowiczianum*, and *Acer distylum*, along with the palmate leaves of *Acer palmatum* subsp. *amoenum* and the now-familiar *Acer nipponicum* and *Acer mono*. We even came across a single *Acer diabolicum*, a rare and elusive species, standing on its own. This maple diversity was exciting because we suspected that two of our target taxa, *Acer carpinifolium* and *Acer capillipes*, grew here.

As we ventured on, we found towering stands of *Zelkova serrata* with their characteristic exfoliating and rippling bark. What stood out about these trees was both their astonishing size and their straight central boles. In the cultivated flora of *Z. serrata* across North America, the species typically features a straight trunk rising to around 2 to 3 meters before branching into multi-stemmed tree. This fan-like form is the dominant phenotype of cultivated trees, which can cause structural issues due to the common occurrence of included bark. To see these wild-type zelkova with long straight trunks reaching high into the forest canopy broadened my view of the species.

Further along the trail we spotted the familiar modeled bark of *Stewartia pseudocamellia*. It was a delight to see it in its native habitat, reaching some 15 meters (50 feet) into the forest canopy. Venturing on, we started to detect a sweet scent wafting through the air. The fragrance of cotton candy on the wind excited the senses, indicating that a Japanese katsura may be nearby. It didn't take long to find the source of the smell. Uphill from the trail, we set eyes on the most massive Japanese katsura (*Cercidiphyllum japonicum*) I've ever seen in my life. The tree had an upright, multi-branching, umbrella form that easily towered 27 meters (88 feet) into the air and featured an unusual bulbous bole some 1.5 meters (5 feet) off

the ground. Awed by this forest giant, I approached it slowly, taking in its grandeur. Michael took out a DBH tape, measuring the diameter at 1.72 meters (5 feet 7 inches), and we recorded the GPS coordinates. While these data may be helpful in our collecting notes, it also was our way of showing respect to this grand old tree and stealing a few more moments of time with it.

In Japanese folklore, *kodama* is the name of the spirit that dwells within old trees. I found it fascinating that Japanese culture has developed a vocabulary to describe that energy. In Western culture, such notions are often associated with spirituality or mysticism. Most everyone I know, spiritual or not, has had some experience when they were awed by the natural world. To stand with this katsura, connecting with an organism that has been present on Earth for generations, it felt possible to sense its *kodama*, or at least my interpretation of it. How fortunate we were to have such an experience, and to know such elder organisms are found and protected in our natural world.

Traveling up the river, we reached a small waterfall. We found our first target plant species of the day, *Deinanthef bifida*, growing amongst the wet seeps on the riverbank, where it created an attractive, low cover about 30 centimeters (1 foot) off the ground in the shade of arching katsura trees. This obscure member of the Hydrangeaceae features distinctive bifurcating leaves. We made our first collection before continuing along the river.

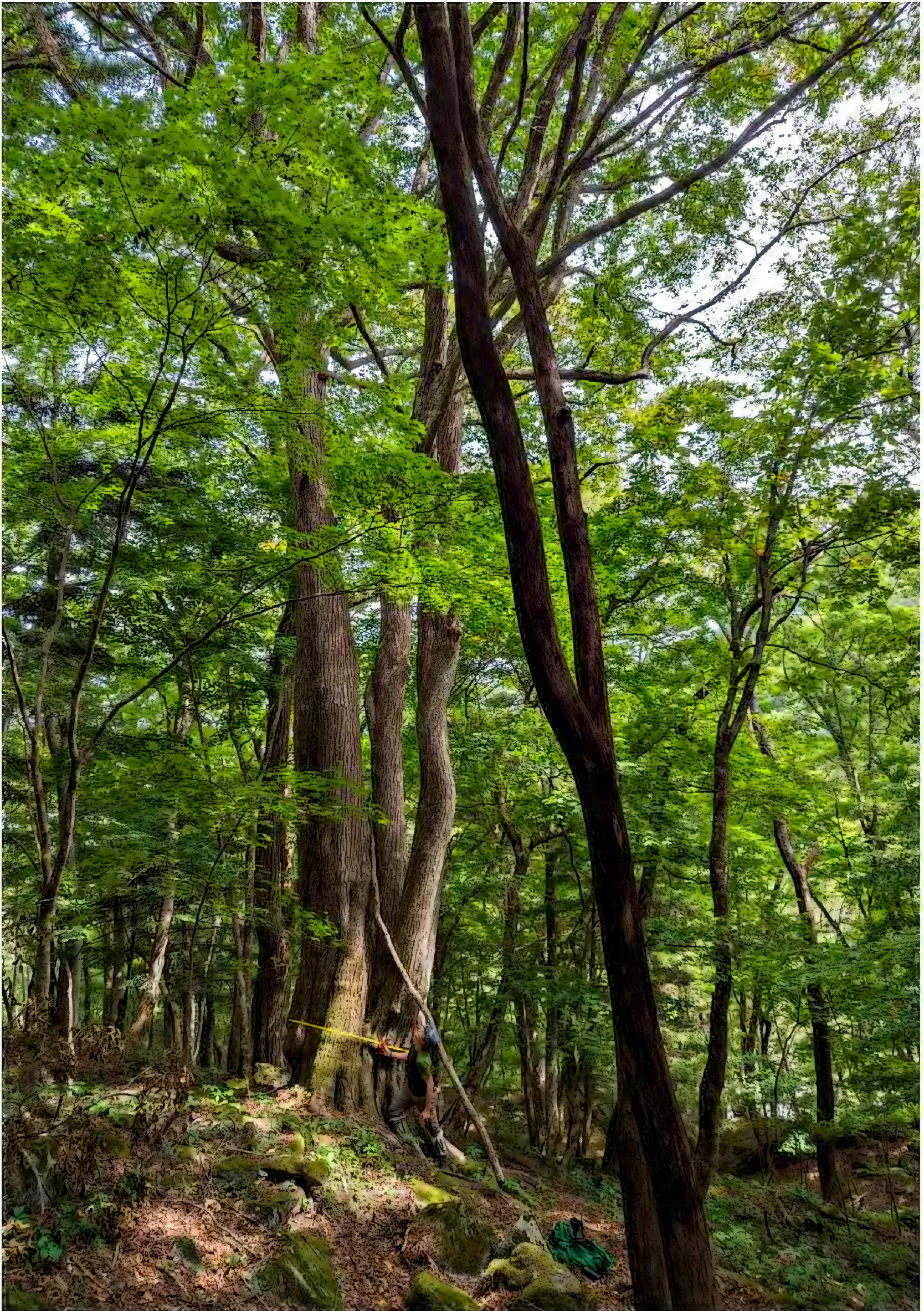
Throughout the day, we saw one of our primary maple targets, *Acer capillipes*, along the riverbanks, exhibiting their dark green to almost black snake bark. We searched each one, hopeful for fruits, yet time after time we came up short. Reaching the end of a trail, we took in a stunning view of Kitashōji Falls cascading some 122 meters (400 foot) off the mountain. As we swiveled from taking in geologic beauty to scanning the flora, we noticed, arching over the river, an eight-meter (25 foot)-tall *Acer capillipes*. This individual happily greeted us with thousands of ripe samaras lightly trembling in the mountain breeze. We excitedly gathered pole pruners and herbarium presses as we started to bag the maple's winged fruit. After we finished recording field notes, we made a final search of the area. Up a small auxiliary stream, we came across the distinctive, double serrate, unlobed, not-so-maple-looking leaves of *Acer carpinifolium* in fruit. If it weren't for dangling winged samaras indicating it was a maple, it would be easy to mistake this tree for a Japanese hornbeam

(*Carpinus japonica*). Mineaki scrambled up the steep wet stream bank to reach the tree. Using pole pruners, he handed down seed-laden branches to Yoshinari, who passed them to Michael, who then passed them to me in the equivalent of a botanical bucket brigade transporting the fruits of our discovery. With *Acer capillipes* and *Acer carpinifolium* added to the list, this brought our total count of maple taxa encountered along the Ishikara River up to nine—a striking amount of botanical diversity in a small geographic area. After wrapping up our collections and bidding a final farewell to the cascades of Kitashōji falls, we turned back along the river valley. Nearing the end of the trail, we took in a final view of the river, and to our surprise came across a second fruitful *Acer capillipes* growing on a small island. Yoshinari, spry as sika deer, scrambled across the river's torrent and irregular rocks to collect more seeds. After adding the maple seed to our collections, we made our way back to the car, sore but happy, and relieved to have avoided any run-ins with the land leeches that call this forest home.

Mount Fuji

The last stop on this leg of the collecting trip would take us to the mid-elevation (1469 meters, or 4820 feet) forest of Mount Fuji. Driving towards Fuji, on September 21st, we caught views of the volcanic cone peeking through clouds. These glimpses of the mountain transported my mind into the woodblock imagery of Katsushika Hokusai's *Fine Wind, Clear Morning (Red Fuji)* as I imagined us searching for plants amongst the miniature forests depicted on this print. Ours was decidedly not a "clear morning," however, as we drove into the low cloud blanketing the mountain. Arriving at Mizugatsuka Park we were greeted with blustering winds, low visibility, and drizzling rain. Despite the foul weather, our team was excited about the opportunity to experience the flora of this iconic mountain.

We were in search of a single target plant species, the sawtooth stewartia (*Stewartia serrata*), which has been an elusive species for the Arboretum to grow in the past. The Arboretum has attempted its propagation nineteen times since 1936, but it has proven difficult to grow, with only three plants ever making it into the landscape. Perhaps through a combination of sensitivity to cold or poor site selection, none of these individuals survived longer than a decade in the ground, and currently, no living accessions grace our landscape. All previous attempts



The author takes the measure of massive Japanese katsura (*Cercidiphyllum japonicum*) in Minami Alps National Park. Photograph by Michael S. Dosmann



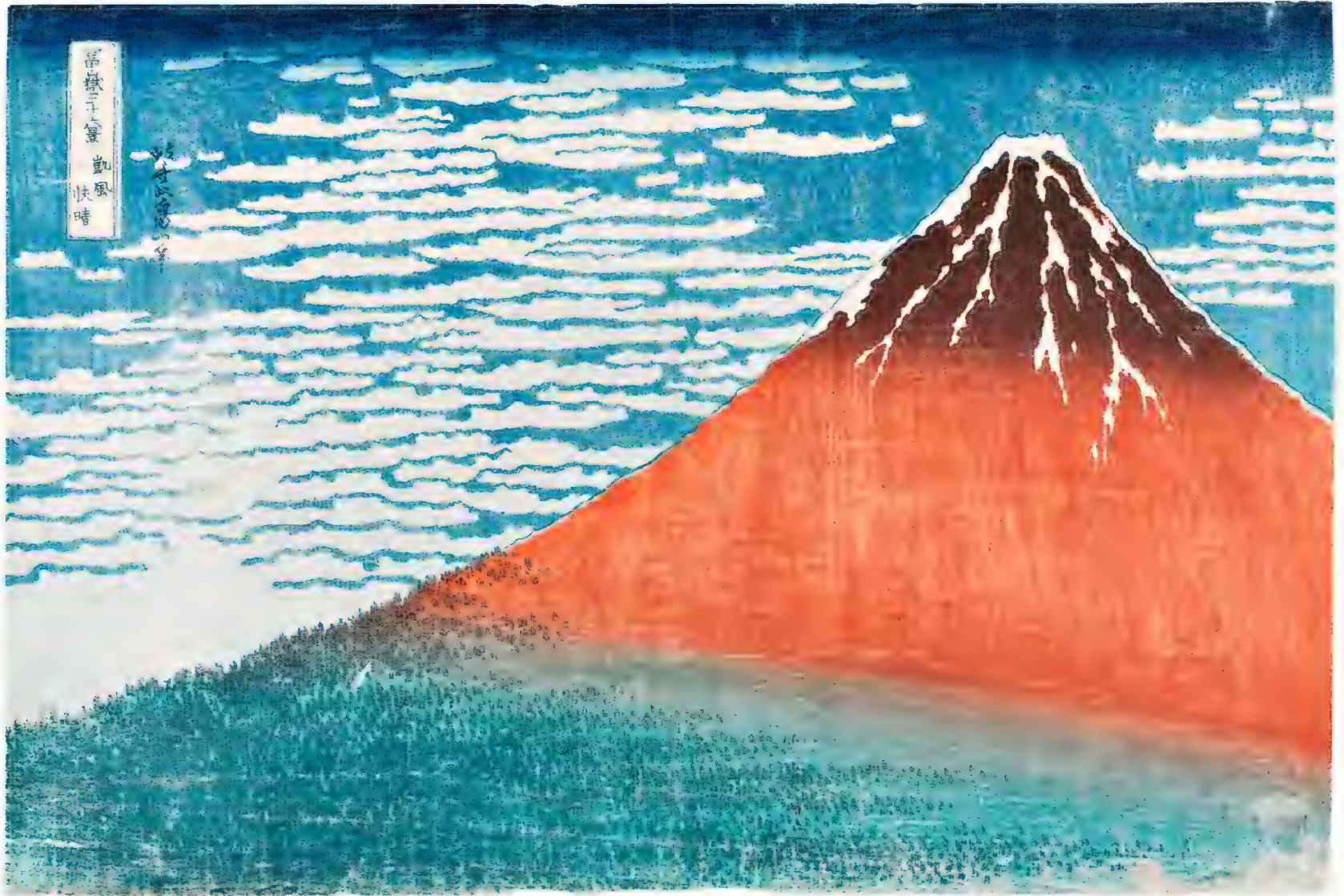
The understory was not the only hint of disequilibrium in the landscape.



Top left: In the Tambara Highlands, a forest of Japanese beech (*Fagus crenata*) with commonly associated broadleaf bamboo (*Sasa kurilensis*) growing throughout the understory. Photograph by Miles Schwartz Sax

Bottom left: Dr. Mineaki Aizawa (right) and his undergraduate student Yoshinari Hata (left) cooperate on a precarious streamside collection of *Acer capillipes*. Photograph by Michael S. Dosmann

Above: *Stewartia serrata* in fruit made for a crucial collection on Mount Fuji. Photograph by Miles Schwartz Sax



Katsushika Hokusai 葛飾北斎; Published by Nishimuraya Yohachi 西村屋与八, *Mount Fuji Viewed during a Fine Wind on a Clear Morning (Gaifū kaisei)*, from the series *Thirty-Six Views of Mount Fuji (Fugaku sanjūrokkei)*, Harvard Art Museums/Arthur M. Sackler Museum, Gift of the Friends of Arthur B. Duel, Photo ©President and Fellows of Harvard College, 1933.4.2699

of growing this species came from cultivated or unknown provenance, so collecting seed from a wild population would be a notable accomplishment for the expedition.

Starting into the forest, we were transported to a different world, as the blustery winds made the trees dance in kinetic motion. The light diffusing through low gray clouds created an ethereal hue. Rain came and went as we hiked across the mountain. Fuji is a landscape of active change, at least on geologic time scales, with its most recent eruption having occurred in 1707. Although the forest has since returned, echoes of this event persist in the thin, micronutrient-rich soils that have developed from the weathering volcanic ash and decomposition of vegetation. The forest was a mixture of mature large canopy trees, such as *Quercus mongolica* var. *crispula*, *Abies homolepis*, *Acer mono*, and *Fagus crenata*. Undulating mounds of moss-covered lava flows punctuate the landscape, creating a mosaic of growing substrates where native *Chamaecyparis obtusa* can be found.

After walking for about twenty minutes, we set eyes on our prize: the first stand of *Stewartia serrata*, made up primarily of small-diameter trees growing up to nine meters (30 feet) tall with deep glossy-green leaves. The bark of this species is diagnostic, with black radial scars found on most stems and small, subtle patches of exfoliation periderm revealing a mosaic of browns, grays, and cinnamons. Although the bark is far less showy than its comparatively flamboyant relative, *Stewartia pseudocamellia*, the sawtooth stewartia is more subtle in its character. The gray hues of the low cloud provided the perfect contrast for spotting *Stewartia serrata*'s cinnamon bark. With our eyes trained in, we quickly were able to identify dozens of trees scattered across the mountain side. As we collected sawtooth stewartia across the site, we found an array of accompanying small trees, such as *Cornus kousa*, *Viburnum sieboldii*, *Stewartia pseudocamellia*, and large shrubs like *Deutzia scabra*, *Abelia spathulata*, *Viburnum wrightii*, and *Viburnum plicatum* var. *tomentosum*. We encountered another

singular *Acer diabolicum* here amongst the forest canopy, solidifying its reputation as a solitary, reclusive taxon.

This forest differed structurally from the other sites we had visited on the trip, and it was far easier to navigate the understory. We soon got the first clue as to why the walking was easy. We came across a high fence that blocked out a square in the forest approximately 10 meters by 10 meters. The fenced area had a thicket of young trees and understory growth that was absent in the surrounding landscape. This was a deer exclosure, one of a series that had been set up to study the effects of forest regeneration in the absence of ungulate pressure. As deer populations have increased in recent decades, they have decimated the understory plant communities, preventing new recruitment of tree saplings or growth of dominant vegetation types like dwarf bamboo (*Sasa borealis*).

The understory was not the only hint of disequilibrium in the landscape. From time to time, we would come across standing dead *Quercus mongolica* var. *crispula* that had been killed by Japanese oak wilt (*Ruehmaphelenchus* sp.). This wilt has become an increasingly devastating tree pathogen in Japan vectored by native ambrosia beetles and nematodes. The oaks of Mount Fuji have become an important study population for this disease, with a new species of oak wilt (*Ruehmaphelenchus fujensis*) being described in the area as recently as 2021 (Kanzaki, 2021). While the loss of oaks was sad to see, the dying trees provided substrate for decay organisms, and we were treated to see large flushes of sulfur shelf fungi (*Laetiporus* sp.). As we continued, however, the weather turned increasingly sour. Completing our collections of *Stewartia serrata*, we headed back to the car to wrap up our day, dry off, and start on our several-hour drive back to Utsunomiya.

Still ahead on our journey would be a trip to the semitropical island of Kyushu in search of *Platycrater arguta*, *Malus spontanea* and *Tilia kiusiana*—not to mention days in the lab inspecting, cleaning, and preparing for shipment the twenty-one collections of various taxa we ultimately made during the 2023 Japan Expedition. As we grow these seeds into trees that will populate the Arboretum landscape, the ecological observations we made in the field will help guide our cultivation of this germplasm. With any luck, these plants will reach their roots deep into soil, weather many storms, grow old—and perhaps, one day their *kodama* will be felt by those who roam the collections of the Arnold Arboretum. 🌿

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Resiliency in the Managed Landscape: The Case for Hickories

By Brandon Miller

What does “resiliency” really mean in the context of managed trees in the landscape? For horticulturists like me, situated in the Upper Midwest, you might think our priorities focus on cold hardiness—and you wouldn’t be wrong, we certainly value trees that can survive our frigid winter temperatures. But from my perspective, “resiliency” better aligns with a well-rounded suite of characteristics, especially those that can aid a tree to survive in a world of extremes. In recent years in Minnesota, we have experienced the expected low winter temperatures typical for our region, but we have also endured atypical weather events during the growing season: floods in the spring and severe droughts in the summer. This erratic range of conditions seems to define our climatic expectations for the future: a world of extremes. So, what is a horticulturist to do when they need to select a tree that they want to survive in our changing climate? Instead of screening species suited to one end of a stress-spectrum, we are looking for those “resilient” taxa that offer flexibility in the face of a variety of stressful conditions. In other words, plants that are adaptable, which offer plasticity—the species that can “roll with the punches,” so to speak. But it doesn’t end with just tolerance to weather conditions; also of interest are plants that can diversify our plant palettes with reduced pest and disease vulnerabilities; those with strong branch attachments; and to top it all off, it wouldn’t hurt if they offered some ornamental appeal along the way! This is a tall order for trees adapted to my region (USDA cold hardiness zone 4b) and one of the few groups of plants that can deliver on this bold request is the hickories (*Carya* spp.).

My Experiences with Hickories

My first interactions with hickories date back to my childhood, growing up in a Northwest suburb of Chicago and visiting my grandparent’s acreage situated just outside of suburbia. The acreage comprised an alfalfa field behind the house and a well-groomed landscape in the front of the property that resembled a golf course, a turfed space complete with an assortment of mature shagbark hickories and bur oaks. This haven of hickory, along with nearby woodlands, were my favorite places to play and explore as a kid. I fondly remember autumn there,

This kingnut hickory (*Carya laciniosa*) was the first tree planted at the Minnesota Landscape Arboretum. Photograph by the author



when the ground was covered in split husks recently fallen from the canopy and littered with bright-white shagbark hickory nuts, overwhelming busy squirrels attempting to stash them away before winter. These projectiles, along with strips of exfoliating bark and a stray branch or two, became integral components of childhood games. It wasn't until years later, when taking a plant identification class as an undergraduate at Iowa State University, that I learned these magnificent trees were not widely available in the nursery trade. Our class was told that in the green industry, claims of protuberant taproots, which impede their ability to be successfully transplanted, and a general consensus that they grow too slowly to turn a profit, were mainly to blame. The thought that hickories could not be sought out and planted to grace a home landscape was disturbing. My childhood memories of playing in the shade of old shagbark hickories were experiences that could not be replicated elsewhere. Surely, this was a mistake! I took to the internet and the library seeking contrary evidence, only to confirm that my instructor's perspective seemed to be shared widely. But what about other trees which have taproots and grow slowly? Are all the hickories limited by these issues? Is there anything to be done to resolve these problems? These questions led to further discussion with my instructor, an undergraduate research project, a master's thesis, and later a doctoral dissertation, each focused on the central theme of supporting hickories as nursery crops and landscape options. Through these projects, I found evidence that not all the rumors about hickories were accurate, and I explored alternative strategies for propagating, cultivating, and transplanting hickories. With the help of my mentors, we have made some strong cases that hickories should be given more attention in the green industry—because as it turns out, these stately trees could be valuable tools for developing the resilient landscapes of the future.

The Genus *Carya*

The genus *Carya* comprises nineteen species worldwide, a number which varies slightly based on who serves as your favorite botanical authority. The genus is further subdivided into three sections: Apocarya, which hosts the “pecan hickories,” *Carya*, encompassing the “true hickories,” and Sinocarya, the section containing species originating from Asia. Each section is defined by the morphological traits that unify the several species within that section. For example, all the pecan hickories offer “naked” (valvate) buds

whose edges touch but do not overlap, while those in the true hickory group all boast overlapping (imbriate) scales on their terminal buds. These traits not only help taxonomists to group hickories, but they are quite useful to the passive observer in narrowing down a species-level identification. Combined, the two sections previously mentioned yield fourteen species endemic to North America, with all but one, *Carya palmeri* (Mexican hickory), occurring naturally in the eastern half of the contiguous United States. With species spanning such a vast range, it should come as no surprise that these hickories yield an awe-inspiring diversity of ornamental traits and site-specific adaptations that should be embraced and utilized by horticulturists.

Hickories in Horticulture

The genus *Carya* is a group of plants near and dear to my heart. Having studied their intricacies throughout my graduate career while characterizing their horticultural potential and exploring workarounds for their undesirable production-related challenges, I can safely admit my bias for these stately trees as landscape options. But really, what's not to like? Arguably, hickories are some of the most ornamental trees for northern gardens in the temperate zone. They are stately, long-lived, woody perennials, all becoming upright trees at maturity except for one taxon, *Carya floridana* (scrub hickory), which remains a shrubby, multi-stem plant. Among the multitude of traits that define the potential value of hickories for adorning landscapes, the foremost is their bark. Particularly valued by us northern gardeners, bark is a characteristic to be appreciated year-round, especially during the long winter months. For this reason, the shagbark hickory (*Carya ovata*) is one of the most iconic of this genus. At maturity, shagbark hickory exhibits long, exfoliating strips of bark, which peel away from the trunk to create a dramatic effect in the landscape. However, not all hickories display exfoliating bark. Some, like *Carya tomentosa* (mockernut hickory), exhibit a strongly ridged pattern while others, like *Carya illinoensis* (pecan), reveal a scaly texture. Bark traits vary significantly both within and across taxa, but each can appeal to the appetites of ornamental horticulturists. The second characteristic for which hickories should be known is their autumnal display. Hickories provide some of the most intense and vibrant yellow-to-orange fall foliage displays among northern-adapted trees. Most, if not all, of the hickories can display bright, brilliant yellows, but



Bark variety in *Carya*: the peeling strips of shagbark hickory (*C. ovata*, 22868*A, top left); the scaly texture of pecan (*C. illinoensis*, 12913*A, top right); the ridges of mockernut hickory (*C. tomentosa*, 20100*B, bottom).



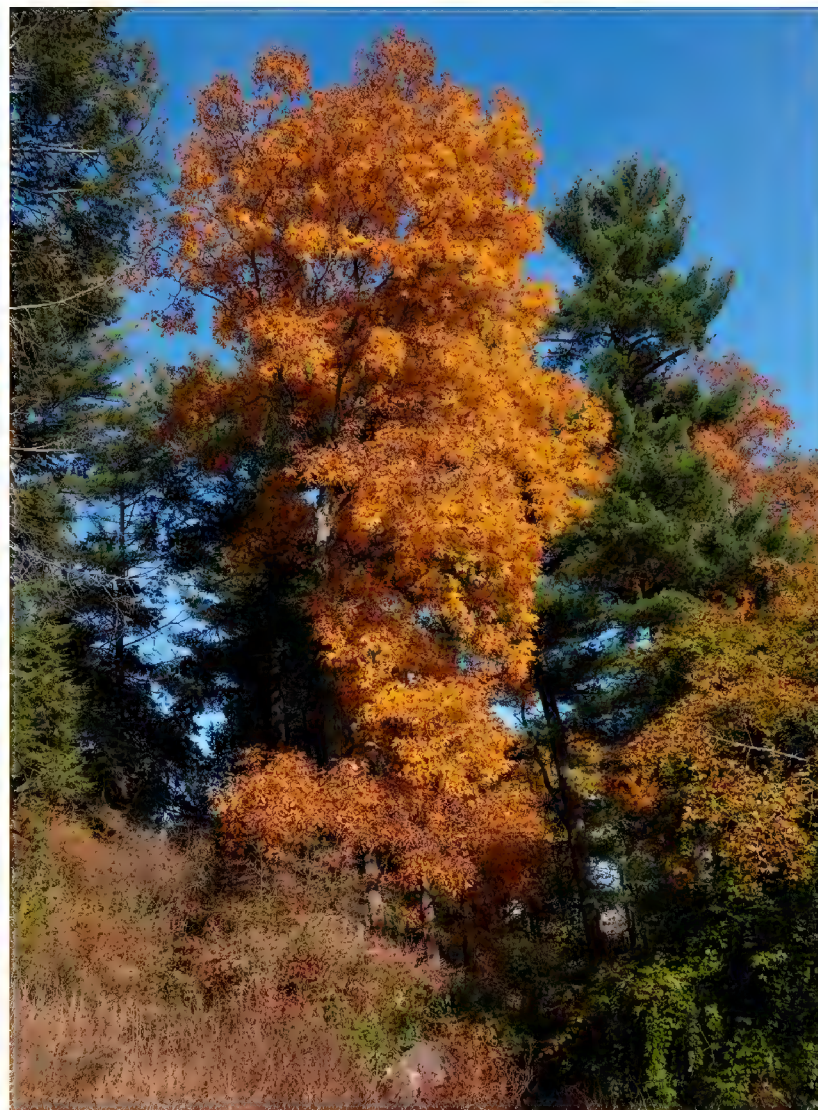
Studies in form and color: bitternut hickory (*C. cordiformis*, left) and another view of the kingnut hickory (see page 35), both in the Minnesota Landscape Arboretum. *Photographs courtesy of the author*

my personal favorite is the awe-inspiring amber color of *Carya glabra* (pignut hickory) leaves in autumn. It is hard to convey the vivid color of pignut hickory leaves in the fall other than to say the rich amber color is, in my opinion, superior to the display of any other tree we grow in the Upper Midwest.

In addition to their superb ornamental capacity, species belonging to the genus *Carya* should also be praised for their lack of susceptibility to pests and diseases, as well as their cold hardiness. The former attribute varies slightly across regions where hickories and pecan are cultivated because no group of trees is completely immune to pests and diseases, but the overwhelming trend across taxa is a lack of a notable “Achilles’ heel.” Cold hardiness is a trait that has never been formally screened across the genus but based on efforts to cultivate *Carya* spp. in cold climates, multiple taxa are particularly tough. In Minnesota, both bitternut and shagbark hickories are native to the state, with the former occurring naturally throughout regions characterized as USDA zone 4. The latter naturally occurs only in the southeast portion of the state, but is suited to cultivation throughout USDA zone 4 (average annual extreme minimum temperatures

ranging from -34.4°C to -28.9°C). In 1957, at the University of Minnesota Landscape Arboretum, a specimen of *Carya laciniosa* (kingnut hickory) was the first tree to be formally planted on the site and later accessioned into the collections. The tree still exists today, appearing healthy and vibrant, serving as a testament to the amenability of this taxon to expanded planting outside of its native range. Lastly, our collections also include a variety of northern pecans (those which originate from the northern part of the taxon’s native range) which take on a small-statured form of less than forty meters tall in our climate.

Hickories adorning a landscape can provide some outstanding coarse structure to a design. When I observe hickories—and only after I have finished admiring their bark—I am usually drawn to their branch architecture. With few exceptions, most hickories display a clear dominant leader, and they rarely break apart—a testament to their strong branch attachments. Mature trees tend to be taller than they are wide, even when grown without nearby competitive vegetation. Aside from their visual appeal, I appreciate how often when I view a hickory, the sight is accompanied with some form of wildlife. Species



Pignut hickory (*C. glabra*, 7873*A, left) and shagbark hickory (*C. ovata*, 22868*K, right) in the Arnold Arboretum. Photographs by Kyle Port (left) and William (Ned) Friedman (right)

belonging to the genus *Carya* offer immense ecological value, whether in a wild setting or in a managed landscape. Hickories have strong ecological connections to a vast array of wildlife—and further, as long-lived, durable plants, they provide many ecosystem services to the sites where they are grown.

One might wonder why a genus that can offer so many unique qualities, and even comprises an agriculturally significant taxon like pecan (*Carya illinoensis*), seems to have been largely ignored by commercial horticulture. The fact of the matter is that hickories have been overlooked because they are slow to produce a saleable tree when cultivated from seed, asexual propagation techniques suited to developing trees for ornamental landscape applications are lacking, and they are almost exclusively defined by their development of a taproot—which is often said to limit their ability to be transplanted. In their current state, they serve as the “poster child” for a challenging crop in the nursery.

Hickories in the Landscape

To qualify as a resilient landscape option, at least as I have previously defined, a tree should be tolerant

of various soil-moisture conditions. North American hickories include species adapted to dry upland sites, like *Carya tomentosa* (mockernut hickory), species found in seasonally inundated swamps, including *Carya aquatica* (water hickory), and those such as *Carya ovata* (shagbark hickory) that often are observed somewhere in the middle of that spectrum. These species can be sited well in landscapes with well-defined soil-moisture characteristics (i.e. frequently dry, often wet, or “average” moisture), but the truly distinctive taxa that demonstrate a capacity to tolerate both flooding and drought are likely the resilient trees capable of thriving in the future. On a grand scale, one might wonder if this diversity of adaptations within the genus *Carya* could be drawn upon for the long-term endeavor of selecting and breeding stress-tolerance traits into a resilient selection. This idea is plausible because many of the hickories, including those in different sections, are known to be capable of hybridization across species lines. In fact, several documented interspecific hybrids are known to occur naturally in the wild where the ranges of their parent species overlap. An unfortunate reality, however, of idealizing a hickory breeding program to



The author in the Arnold's plant propagation facility with a tray of seedlings he gifted to the Arboretum (opposite). Photographs courtesy of the author

provide superior specimens for landscape use is the long maturation period of these stately trees, which would almost certainly require multiple generations of plant breeders before yielding major progress. So, where should a horticulturist with finite time begin with this process? Luckily, the timeline to obtaining superior selections can be greatly reduced because the genus *Carya* already offers species such as *Carya cordiformis* (bitternut hickory) and *Carya laciniosa* (kingnut hickory) which—combined with observations of these trees growing naturally in inundated riparian habitats—recent research suggests are also quite adaptable in the face of drought.

Researchers keen on identifying trees for the future have employed a variety of physiological screening tools to characterize stress tolerance thresholds. In recent years, vapor-pressure osmometry, a technique originally developed for ecological research, has been embraced in the horticultural realm to characterize drought tolerance by predicting a taxon's leaf water potential at the turgor loss point. While water relations for plants is a complex concept and a multitude of factors are involved in the process, this predictive tool has become a staple for

researchers because it can fairly easily and quickly be employed, and it measures and predicts a metric that many plant scientists agree can be equated to a tree's tolerance threshold for drought. Essentially, the leaf water potential at the turgor loss point can be thought of as the minimum water potential threshold that a tree can endure while simultaneously not incurring permanent injury to the tree. This "sweet spot" for drought tolerance can be used as a metric to rationalize the characterization of this trait with a number; it can help inform site specifications in landscapes to match the right plants in the right places; and it can be used to directly compare tolerances across taxa, thus generating relative tolerance rankings and providing resources for those designing a landscape.

While studying at Cornell University in 2019, I led an experiment to replicate this technique with five species of hickory: *C. cordiformis*, *C. glabra*, *C. illinoensis*, *C. laciniosa*, and *C. ovata*. This span of taxa encompasses species that occur naturally in a variety of landscapes—growing on upland sites and ranging down to bottomland riparian habitats. The goal was to capture this diversity to determine where, on a relative scale, the species fell on the drought-



tolerance spectrum. Old forestry literature suggested that drought tolerance would increase with species adapted to upland conditions and would decrease with those often found in bottomland habitats. However, to our surprise, our data suggested the exact opposite. Instead, we observed a trend wherein the species which occur naturally in bottomland habitats (*C. cordiformis* and *C. laciniosa*) were predicted to be more drought tolerant than their upland counterparts. The upland counterparts were still fairly drought tolerant, but interestingly their bottomland cousins were exceeding expectations. At first, we wondered why this might be. Did we do something wrong? We repeated the study in 2020, only to yield the same results. We looked to the literature and discovered a pattern with some other bottomland taxa that, contrary to expectations based solely on their site association in the wild, were incredibly adaptable to droughty conditions. What appears to be the trend across these species is their localization in bottomland habitats which are characterized not only by seasonal flooding but also periodic droughts. Is it possible some riparian habitats are resulting in water conditions that ebb and flow between drought and

flooding, thus creating a natural selection process for resilient plants? We thought so. A classic example that many horticulturists can connect with is *Taxodium distichum* (bald cypress). In the wild it can be found in swampy bottomland conditions, but when cultivated the plant is adaptable to a range of landscape scenarios, including droughty situations. So, what does this tell us? For one, we don't think this trend suggests that all bottomland plants are necessarily drought tolerant. Rather, it suggests that there is more than meets the eye for some plants found on riparian sites, and some of those locations could yield incredibly adaptable plants that will perform in conditions we wouldn't necessarily expect after viewing them in the wild. Second, it supports further screening of a multitude of taxa not only to evaluate stress-tolerance factors on one end of a stress spectrum, but to look for the species that may exhibit plasticity, which ultimately might serve as resilient icons in the landscapes of the future. Lastly, this trend reminds us not to use broad-brush generalizations when it comes to any genus. In this case, hickories should be considered for their resiliency, adoption in the nursery, and their application in the landscape on a case-by-case basis to match the right plant with the right conditions, situation, or place.

At the end of the day, hickories are a highly underutilized source of ornamental characteristics and stress-tolerance traits for managed landscapes. They offer a range of attributes and are adapted to a multitude of site conditions. Horticultural improvement efforts could expand opportunities for embracing hickories in the landscape, and their inclusion in managed settings could mean improved species diversity and landscape-level resiliency in the green-spaces of the future.

I fondly recall my memories of growing up with hickories, conducting research, and appreciating them *in situ*. I hope that my experiences can be shared by the next generation of horticulturists and those that follow for many years to come. 🌿

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ANNALS OF ARBORICULTURE

Untangling the Issue of Circling Roots

By Bert Cregg and Riley Johnson

Container-grown trees seem to be everywhere—but as anyone that has planted one can attest, the root systems of such plants often are a circling, matted, tangled mess. Over the past 12 years, Bert Cregg's lab at Michigan State University has investigated the physiology of improving establishment of container-grown trees. In what follows, Dr. Cregg will explain the genesis of this program and the initial trials, which focused on one treatment applied to a single cultivar, and research technician Riley Johnson will discuss research she undertook for her master's thesis, expanding the lab's trial program to other species and treatments.

Why do nurseries want to produce trees in containers? Growing trees in plastic containers filled with lightweight media—made up primarily of pine bark or Douglas-fir bark—provides advantages to nursery producers because container production uses space more efficiently than field-production and eliminates the loss of soil each time a balled-and-burlapped (B&B) tree leaves the farm. Container growing also increases tree growth and allows growers to turn trees over faster in

Baring roots with an air spade to assess pre-plant treatment (left), and container-grown trees at the Michigan State University Horticulture Teaching and Research Center awaiting the next transplant study (right). Photographs by Dana Ellison-Smith (left) and Bert Cregg (right)



the nursery. It also eliminates the loss of tree roots that occurs in digging balled-and-burlapped (B&B) trees, occurrence of which can go as high as 90 percent, according to a study by Watson and Himelick (1982). More importantly, container trees weigh much less than similar-sized B&B trees, often eliminating the need for heavy equipment to handle trees on a planting site.

As soon as we remove the container, however, the downside to container-grown trees becomes apparent: circling roots. As soon as a tree is planted in a container at the nursery, its roots begin to grow outward. Encountering the sidewall, the roots deflect sideways and begin to follow the contour of the container. As the roots continue to develop, they lignify, putting on wood, and thus these circling roots become a permanent root deformity. If circling roots are not corrected when the tree is planted, they can have several negative consequences; they limit the amount of root egress outward into the surrounding backfill, which slows tree establishment and reduces tree stability (Gliman and Masters, 2010; Gilman et al., 2010), and they ultimately contribute to stem-girdling roots, which can reduce vigor and even threaten tree survival (Johnson and Hauer, 2000).

Horticulturists have been dealing with the question of what to do about circling roots for nearly as

long as nurseries have been growing trees in containers. Over the years, researchers and practitioners have tried a range of methods to mitigate circling roots on container-grown trees and shrubs, including teasing (physically disentangling roots), slicing or scoring (making a series of vertical slits in the root system to disrupt the circling roots), and butterfly-ing (making one or two slices through the bottom of the root system and splaying out the ends). As often happens in arboriculture, research trials on mitigating circling roots yielded mixed results, and there was not a clear consensus on the best approach. In the early 2000s, Dr. Ed Gilman and his research group at the University of Florida conducted a series of trials on pruning roots of container-grown trees. In particular, they focused on “shaving” root systems—that is, using a saw or sharp spade to remove the outer periphery of roots from the rootball and the “pancake” mass of roots that typically forms in the bottom of the container. A key finding from these trials is that shaving root systems not only reduced circling roots but stimulated new outward root growth that improved tree stability—a key and important consideration in hurricane-prone Florida. However, as a tree physiologist, my immediate concern is the potential of root shaving to increase transplant stress on trees—not to mention stress on propagators (for



Outgrowing their containers (top), circling roots take the shape of their container (center), eventually lignifying into permanent impairment (bottom). *Photographs by Bert Cregg*

Horticulturists have been dealing with the question of what to do about circling roots for nearly as long as nurseries have been growing trees in containers.

those who have never done it, root shaving is not for the faint of heart). Shaving removes a lot of roots, many of them fine roots that perform the critical functions of water and nutrient uptake. In our trials we've removed up to one-third of the total root biomass—though the proportion of fine roots removed is even higher, since they are concentrated in the outer portion of the root system that we're shaving off.

Starting in 2012, my lab began a series of trials aimed at the question of mitigating circling roots and tree stress. We had over 100 'Bloodgood' London planetrees (*Platanus × acerifolia*) in 25-gallon containers in our pot-in-pot nursery at the MSU Horticulture Teaching and Research Center (HTRC). The trees had been grown in the containers for two years, had plenty of circling roots, and were prime candidates for a trial. I knew I wanted to look at shaving, but wanted to consider other factors as well. These first trials trace back to my involvement with the Garden Professors Blog, whose avid readership offered a wide array of horticultural expertise and curiosity. I polled the blog readers, who selected two evergreen questions: the effect of fertilization at planting and at mulching. Based on this information, we installed two trials in spring 2012.

The first trial was installed as a combination of three root treatments (shaving, teasing, and untreated control) and two fertilizer treatments (with and without). For the shaving treatment, we removed the outer one inch of roots around the periphery of the root systems with a pruning saw. For the teasing treatment, we disentangled the roots with a garden fork. The fertilizer treatment was an addition of 400 grams of controlled-release fertilizer, which is what the trees received each year when we grew them in the nursery. We tracked growth of the trees for two years and then dug up a subsample of trees with a 48-inch tree spade and cleaned the soil from the roots with an air spade. Fertilization at planting did not impact tree diameter or height, which is consistent with many studies (Day and Harris, 2007; Harris et al., 2008). As we began to unveil the root systems, however, the root-treatment effects were immediately apparent. The imprint of the original plastic container was evident on all the control trees, whereas the trees that had been teased or shaved clearly had fewer residual circling roots and had more outward root growth. We quantified the amount of root egress by trimming and collecting the roots that extended beyond the container, which were then dried and

Different species varied widely in their response to the same root treatments.



Bare-rooting with water exposes malformed or circling roots.
Photograph by Bert Cregg

(Opposite) Despite its extreme appearance, root shaving improves root system quality without detrimental impacts on tree physiology and growth. *Photographs by Riley Johnson*





With root treatment and planting, the work is far from done. Photograph by Bert Cregg

weighed. These data confirmed our visual observation, with shaved roots yielding the most growth, followed by the teased roots, with the control plants exhibiting the lowest yield. In the second part of the 2012 trial, we repeated the root treatments (shave, tease, and control) and crossed these with two mulch treatments (with and without 3 inches of ground pine bark). After four years of observing the trees in the landscape, we again measured tree growth and excavated the root systems. In this case, mulching dramatically increased stem caliper growth (35 percent larger than non-mulched) and height growth (55 percent taller than non-mulched), and shaving and teasing were effective at eliminating circling roots and improving root egress. In this trial, we also measured leaf water potential (a measure of the amount of tension of the water in the tree's xylem tissue, which helps us track plant moisture stress) and found there was no difference in stress for trees that were shaved versus the other treatments (Cregg and Ellison, 2018). In other words, my initial fear, that the root removal associated with shaving would increase transplant stress, was ill-founded. For the planetrees in our trial, at least, shaving was emerging as the most hopeful option.

For the 2018 trial, we wanted to continue evaluating root shaving by trialing the technique with additional species; along with the 'Bloodgood' London planetrees, we also included two other commonly used landscape trees: 'October Glory' red maples (*Acer rubrum*) and columnar tulip trees (*Liriodendron tulipifera*). Another root-modification technique being touted by some industry professionals was "bare-rooting" or "root washing," in which all of the container substrate or soil around and within the tree's root system is removed in order to correct any root defects by pruning them out. Claims of the benefits of these techniques were anecdotal and somewhat controversial (Chalker-Scott, 2020; Cappiello, 2020), and so we chose to include these treatments in our study, too.

With our experimental design, we were able to compare trees across four root treatments: (1) untreated control, (2) root shaving, (3) bare-rooting using water (i.e., "washing" the root systems with a garden hose to remove the substrate, then pruning out any malformed or circling roots), and (4) bare-rooting using compressed air (i.e., blasting away the container substrate using an air spade, then pruning out any malformed or circling roots). We planted all of the trees at the HTRC, evaluated their growth and stress responses, and dug them up after two years. This time, we were able to note how different species varied widely in their response to the same root treatments. Like in the previous trial, leaf water-potential values of London planetrees did not vary across root treatments except for the measurements immediately following planting, and this was the same for the red maples, suggesting they are resilient to root pruning. When measuring the tulip trees, however, we found that the water-potential values among the bare-rooted trees remained low compared to the other root treatment groups, and this ultimately preceded doom for several tulip trees. We also observed a significant amount of leaf scorch and stem dieback among the trees in the bare-root treatments, indicating that the trees were attempting to regain a functional equilibrium and balance the plant's root-to-shoot ratio to minimize critical water loss/difficulty with water uptake (Rouse, 2021).

Bare-rooting via either method did improve the tree root system quality—of those that survived. There was significant mortality among the tulip trees that were bare-rooted, whereas all of the London planetrees across all root treatments survived, and a few red maples died (including a control tree).

Shaving reduced circling roots for planetrees and tulip trees, but shaving did not benefit the dense, fibrous root systems of the red maples. This is why having additional species included in these trials is critical: we cannot generalize how best to care for trees when we know that species will respond differently to any variable.

Most recently, in 2021, we initiated a new study to continue building on our knowledge of these root modification techniques. To better categorize our recommendations around root modification, we chose to use species that are known to be “difficult to transplant” as bareroot planting stock. These species include ‘Emerald City’ tulip tree (unsurprising given our earlier observations), American hornbeam (*Carpinus caroliniana*), and American hophornbeam (*Ostrya virginiana*). We also included the ‘Blood-good’ London planetree as positive control due to the resilience to all root-modification treatments they displayed in previous experiments; London planetrees also are often described as an easy-to-transplant bareroot species. Root treatments for the 2021 trial included: (1) untreated control, (2) deep scoring (vertical slices made using a pruning saw to sever outer circling roots), (3) root shaving, and (4) bare-rooting using water. Additionally, because trees that we bare-rooted in 2018 exhibited such extreme leaf scorch following planting, we also tried compensatory pruning, preemptively reducing crown size to increase the root-to-shoot ratio of a subset of trees in the bare-root and control groups. Averaged across all species, compensatory pruning reduced the amount of crown dieback of those trees that were bare-rooted, but pruning made no difference where roots were left untreated. Compensatory pruning is not a recommended practice in arboriculture; however, our preliminary findings indicate that the practice may be useful to balance the root-to-shoot ratio when removing a substantial amount of root biomass as in bare-rooting.

The trees from the 2021 planting are still in the landscape at the HTRC, and we have been monitoring their growth and physiological responses over the past three years. Thus far, bare-rooting has again been noted as extremely stressful for the “difficult-to-transplant” species. Like the pattern noticed previously, many of the bare-rooted trees (other than the planetrees) underwent critical levels of moisture stress following transplanting, and ultimately died early in the first growing season. In spring 2024, we plan to begin our tree excavation to evaluate the roots

systems and determine if any of the initial treatments decreased root circling caused by the initial nursery containers.

After a decade of research aimed at mitigating circling roots, root shaving has consistently improved root egress and root system quality without having detrimental impacts on tree physiology and growth. In the nursery trade, advancements to the standard plastic nursery container have been made to greatly reduce circling roots, yet in some areas, these alternative container designs have been slow to come to market. Many nursery growers are becoming more conscious of the need to produce higher quality root systems to promote longevity of their trees post-transplant, so they are taking the time and care to root-prune or shave root systems when up-potting their trees, leading to fewer container imprints. 🌿

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VISUAL ESSAY

Embedded Beauty

The Botanical Specimens of Sheila Magullion

Signs in museum and parks declare: “Fragile! Do not touch. No climbing! Stay on the path.” This fragility is especially true of plant material. The fleetingness of a flower, the brilliance of an autumn leaf—how can we examine these delicate intricacies without harming them?

One way to preserve plant specimens is an herbarium, where material is pressed, dried, and stored. But an herbarium is used primarily for scientific research; it must be stored under specific conditions and handled delicately. Its beauty is mostly hidden away. So how can people appreciate what they cannot see?

One intriguing method of preservation exists in the library of the Arnold Arboretum, which houses a collection of embedded specimens—plant material encased in plastic resin that hardens into a solid block, allowing the viewer to study its contents from all angles. Conceived by

With its green tint, churning surfaces, and captive bubbles, Magullion’s embedded specimen of black pine (*Pinus nigra*) seems caught in a block of stop-motion seawater. 5.5 inches high by 5.5 inches wide by 2.5 inches thick. Photographs by Harvard Library Imaging Services, Copyright © 2024 The President and Fellows of Harvard College



horticultural taxonomist Gordon P. DeWolf, Jr., in the 1970s, these beautiful objects were created by former volunteer Sheila Magullion, who passed away in May 2023 at the age of 93. Sheila pioneered the technique of creating these embedded specimens—288 of them, according to Larissa Glasser (who wrote about the collection in 2014)—encasing dried plant material in resin that hardens into a solid block, allowing the viewer to study its contents from all angles.

In a 1976 article for *Arnoldia* (36:265–75), Sheila detailed the intricate embedding process, beginning with drying the plants. “It is essential that the material be quite dry and as perfect as possible,” she wrote, since any flaws would appear magnified, and improper drying could lead to discoloration. She also highlighted the importance of knowing your materials, as specimens react differently to the drying and casting process. From explaining the molds to describing the perfect resin formula, Magullion’s entire process was a labor of love—whose product can be admired to this day, unmatched in preserving a plant’s true form.

—Jamila dePeiza-Kern

Cedrus libani
Cedar of Lebanon
2 Months Cold





Some specimens are germination guides, specifying techniques for preparing seed, including two months of cold stratification for cedar of Lebanon's winged seeds (opposite). 7 inches high by 4.5 inches wide by 2.5 inches thick.

For southern waxmyrtle (above), the sample displays the waxy fruits (*cerifera* means "wax-bearing"), the cleaned seed at center, and then the desired result: a sprightly seedling, crumbs of soil still clinging to its roots. 4 inches high by 4 inches wide by 1 inch thick.





Magullion's *Hamamelis* × *intermedia* 'Arnold Promise' (above), a signature Arboretum hybrid, in an arrangement worthy of a Japanese scroll, its confetti petals unfurled as if on a spring-like winter's day. 4.25 inch diameter, 1.25 inches thick.

Opposite above: an autumnal *Crataegus nitida* (glossy hawthorn) in fruit. 4.5 inches high by 4.5 inches wide by 1.25 inches thick.

Opposite below: *Acer palmatum* (Japanese maple). 4.25 inches high by 4.25 inches wide by 1 inch thick.



The Korean variety of Japanese stewartia, *Stewartia pseudocamellia* var. *koreana*, the oldest living specimens of which were grown at the Arboretum from seed obtained by E.H. Wilson during a trip to Korea in 1917, accessioned the next year. 4.5 inches high by 4.5 inches wide by 1.5 inches thick.



A spray of ginkgo leaves and pollen cones, so tiny they evoke the Arboretum's bonsai collection. 4.5 inches high by 4.5 inches wide by 1.25 inches thick.



Propagations

OUR WARMING WORLD

Fruitless Springs: Waking from Dormancy in the Anthropocene

By Christina Janulis

For us in the Northeast U.S., deciduous trees are impressive indicators of seasonal change. Their growth cycle mirrors our own productivity patterns, as an active summer winds down into a quiet autumn that prepares us for a restful winter, until the warmth of spring re-energizes us for another summer to come. Like us, trees in temperate and boreal regions are sensitive to cold temperatures. Unlike migratory birds or retirees who simply take off and head south for the winter, these sessile trees have had to adapt to cold, dry, light-poor conditions. In late summer or early autumn, they stop growing and sheath their green shoots in hardened buds to protect precious apical meristems. The sight of foliage in warming hues as microscopic chlorophyll factories shut down reminds us, too, that a season of rest is approaching.

Like our own sleep, dormancy is essential to a tree's health, development and wellbeing. Just as we enter various REM cycles each night, there are multiple stages of tree dormancy, which experts have termed paradormancy, endodormancy and ecodormancy. When a tree senses the shorter days of late summer through light-receiving photoreceptor proteins, it produces abscisic acid (ABA), a hormone that works to slow down metabolic activity and induce leaf drop. As a result, the tree slowly enters a deep sleep—endodormancy—when all growth is inhibited internally by the plant. Just as many of us tend to go “offline” during the holiday season, the tree becomes unresponsive to the outside world during endodormancy.

The quiet, complex metabolic processes that continue inside the tree during this stage are still not well understood by science. This may seem surprising, but even many of the molecular underpinnings of sleep regulation in human health

and disease continue to elude us; we know that sleep disruption is associated with consequences for human health, but we do not fully understand which genes control the relationship between sleep disorders and disease. A central component of tree dormancy that greatly influences its health and productivity come springtime is the “chilling requirement.” A tree fulfills its chilling requirement once it has been exposed to sufficient above-freezing temperatures, at which point it is released from endodormancy. Each tree species has a specific chilling requirement (with some intraspecific variation, which emerges through cultivation or changes in response to latitude or climate). This determines when it enters the next stage of dormancy—ecodormancy—which is a lighter sleep that is poised to lift once environmental conditions in spring are favorable for bud break.

When a tree enters the ecodormancy stage, it is once again receptive to environmental signals to bloom. As spring approaches, it waits for critical cues—long days or warmer temperatures—to know when it is safe to open its buds. Bud break timing is everything: too early, and tender shoots are exposed to spring frosts; too late, and there is little time for flowers, fruit or new growth. The chilling requirement protects the tree from opening its buds prematurely during warm spells in the middle of winter by keeping it unreceptive to cues until the worst of the cold weather has passed. Meeting the chilling requirement is key for high blooming rates and uniform flowering in the spring—otherwise, bud break may be irregular and heterogenous.

Today, that chilling requirement is getting harder to fulfill. We are currently in the “Anthropocene,” a proposed geological

epoch used to describe the period of time humans have had significant impact on Earth's climate and ecosystems. The complex consequences of our changing climate play out differently across taxa, cultivar, and landscape. (See *Arnoldia* 76:2, "Dormant Vines, Future Wines," to learn about how climate change is affecting viticulture). Investigating the molecular basis of dormancy—and how growth and sugar profiles change during the winter—is crucial in understanding how climate change will affect how trees wake and function in the spring. While energy metabolism slows to a minimum during dormancy, a complex array of signaling pathways among genes actively regulates the transition between its stages. In the past decade, a slew of studies have found that changes in primary and secondary metabolites in dormant buds are associated with dormancy progression. Many of these studies aim to characterize these pathways with the hopes of finding genetic modifications that can artificially regulate dormancy in buds to ensure that trees get the rest they need under warming conditions.

A team of researchers at the University of Georgia are working to understand which genes are "awake" during dormancy and what their functions may be. In 2022, they were awarded \$2.7 million by the U.S. Department of Energy to investigate how wood-forming xylem cells function during colder months. The researchers have been characterizing a gene they believe is responsible for sucrose distribution during dormancy, and a small field trial has already revealed that the absence of this gene can cause trees to drop their leaves early and flush their leaves late. This preliminary result suggests that without the gene, carbohydrate reserves are negatively impacted. With this information, the scientists can build a foundational understanding of how sugar profiles are regulated at the molecular level throughout dormancy. With further research, they hope that genes or pathways like this one can be altered to protect buds under inconsistent weather patterns. For example, delaying bud break could prevent

The complex consequences of our changing climate play out differently across taxa, cultivar, and landscape.

trees from waking prematurely during a warm snap in early spring.

As for human sleep, research on the consequences of insufficient rest has revealed that it increases risk of cancer, depression, and heart problems, and, according to a 2020 article in the *Harvard Business Review*, it decreases productivity in the workplace. In parallel, dendrologists have been studying the effects of disrupted dormancy in trees, often measuring productivity via flowering rate and fruit yield. Temperate fruit trees are popular study models for this work because the impact of warming temperatures on chilling requirements can be easily observed in irregular flowering patterns and lower, poorer-quality fruit yields. Threatened fruit production also has serious implications for economies, cultures, and food systems worldwide as temperatures continue to rise. While warmer weather can bring temperatures above the chilling range in some regions, slowing the chilling process, it can also raise ordinarily below-freezing temperatures into the chilling range, advancing the chilling process. Both scenarios affect the delicate timing of

Christina Janulis is a budding science communicator interested in landscape history and ocean science who fell in love with the Arnold Arboretum during her time at Harvard.



bud break and render the tree vulnerable.

The Mediterranean Basin has been the subject of several important studies in the past few years, as one of the largest production zones of temperate fruits in the Northern Hemisphere and a climate change “hotspot,” according to the Intergovernmental Panel on Climate Change. Drought and rising temperatures in recent decades have affected bud initiation and differentiation, dormancy, flowering, fruit set, and development. A 2023 study in Tyre, Lebanon, found that the optimal fruiting of olive trees (*Olea europaea*) scales closely with temperature. The researchers used paleo- and present-day data to define the optimal annual average temperature for olive flowering ($16.9 \pm 0.3^\circ\text{C}$), which has remained consistent for at least the past 6,000 years. Their projections predict that temperature increases in Lebanon in the second half of the 21st century will threaten olive-growing areas and drive down productivity, as well as fruit and oil quality.

The olive tree is of great cultural and economic importance in the Mediterranean, which is why agronomists are focusing on

An olive branch for the climate: *Olea europaea* in fruit. Illustration by the author

the dormancy period that prepares the tree for a productive spring. While olive trees are not deciduous (i.e. they do not lose their leaves), they do require a dormant chilling period (ideally between $5\text{--}7^\circ\text{C}$) to flower and bear fruit. During this time, the axillary buds that produce flowers and fruit in the spring are formed, and certain diseases and pest populations are brought under control. The 2023 study found that the olive tree is very sensitive to variations in temperature and precipitation during winter, which ultimately determine when and how it emerges from ecodormancy. A spring that is too wet or dry can also disrupt the optimal fruiting cycle and negatively affect olive production.

In Japan, a 2022 study in *Frontiers in Plant Science* used the Japanese pear (*Pyrus pyrifolia*) as a case study to similarly examine how warming temperatures are negatively affecting cold acclimation, dormancy progression, and floral bud maturation in temperate fruit trees. A physiological condition known as flowering disorder (or dormancy disorder) recently has plagued the pear trees, causing erratic flowering and bud break disorder. These changes

were brought on by a marked increase in mean annual temperature in Japan since the 1990s. After several years of surveying trees in greenhouses and fields, the scientists compiled and analyzed their observations of symptoms, which included delayed blooming, flower bud abortion, fewer florets, smaller flowers, injured or dead flower buds, uneven bud break, and lower bud break rate. Similar phenomena have been observed in New Zealand, Israel, Brazil, and South Africa nearly 30 years ago during springs following mild winters.

The Japanese researchers suggest that changes in levels of dormancy-regulating genes render the pear trees more susceptible to flowering disorder. These widely-studied genes, called Dormancy-Associated MADS-Box (DAM), encode transcription factors that many scientists believe control dormancy progression in fruit trees, including apple, pear, peach, Japanese apricot, and kiwifruit. Their study shows that the trees are not chilled enough during dormancy to support the proper function of genes like DAM that regulate flower development. They also propose that the process of chilling exposure, as opposed to the total amount of chilling, may influence the metabolic processes. Further research into the metabolic regulation of endodormancy release and floral bud maturation would be instrumental in clarifying the physiological basis of this flowering disorder. These scientists hope that characterizing these regulatory pathways can help develop strategies to mitigate or overcome challenges with bud break during the changing climate of the Anthropocene.

Interestingly, the Japanese researchers also found that warm conditions lead to a decrease in carbohydrate accumulation in shoots, which reduces tree vigor. It is possible that the lack of chilling is affecting the function of a gene responsible for sucrose distribution during dormancy, similar to the one that the University of Georgia researchers genetically removed during their field trial that resulted in reduced carbohydrate reserves. While chilling requirements vary across species, there are several

There is an urgent need for models and biomarkers that can help farmers precisely predict when a tree will reach its chilling requirement.

key genes, DAM included, that exist in one form or another across many species; these are known as orthologs—genes that evolved from a common ancestral gene and retain the same function in different species. This provides hope that certain developments can be extended beyond the single study species as they arise.

While scientists continue to characterize the molecular mechanisms of bud break and search for genetic modifications to confer resilience, agronomists and farmers will also need to artificially select species with chilling requirements that can thrive in warming conditions. To do this, there is an urgent need for models and biomarkers that can help farmers precisely predict when a tree will reach its chilling requirement. A study from the Humboldt University of Berlin in 2022 presented the first step in identifying the metabolites related to the timing and length of dormancy phases for ‘Summit’, a cultivar of sweet cherry (*Prunus avium*). The team hopes that these metabolites can be used as biomarkers to indicate the transition between endo- and ecodormancy, which would greatly aid in adaptive species selection.

As trees begin to wake this spring, let the blooming flowers remind you of the months of rest that made them possible. Proper sleep on the scale of days for us can have an impact on the scale of months or years; and, as Katherine May’s 2020 book *Wintering* recommends, we should also take time during our “winters”—be they seasonal or psychological—to retreat and take pause. The unseen molecular pathways that regulate tree dormancy, and those that regulate our own sleep, have been artfully engineered over millions of years to ensure a rejuvenating rest. If we can better understand these processes in trees, perhaps we can try to help them get the rest they need to wake well in the Anthropocene. 🌿

Arboreal

By Rikki Santer

When the March storm wouldn't spare punches
and our front yard elm snapped in half,
its broken body collapsed across the driveway.
The luxuriant crown sprawled across the wet black,
rasped for lost sustenance. Impotent,
I watched from the window and notched
my life with yet another tree:

billowing pink bouffants of dogwoods
that intoxicated my young daddy,
the weeping willows that forgave
my parents' fights—

my brother and I crawling under skirts
of a cul-de-sac's giant pine, our secret
club for beheaded Barbies
and stolen cigarettes—

first kiss along the river
in the sticky hollow
of an oak's furry bosom,
my mother's glow as confidant—

the sheltering pin oak that won
my father's heart when he made
his first downpayment
for an abiding couple's grave—

sentinel twin maples that celebrated
my homecoming from every morning run,
three witness oaks murdered by our
next-door neighbor, grieving crows for days.

Each spring, tree men troll to our front door and swagger
with chainsaws for internment of our broken elm.
But we adore our stubby Pippi Longstocking
in ballerina's fifth position, buoyant
branches sprouting for the sun.

RIKKI SANTER's poetry has been published widely and has received many honors, including several Pushcart and Ohioana book award nominations and a fellowship from the National Endowment for the Humanities. In 2023, she was named Ohio Poet of the Year.



Collecting Samples for Research

By Kathryn Richardson,
Curatorial Assistant

37

Number of
projects served
in 2023

241

Research
shipments
(2023)

Use of the living collections for research is an integral part of the Arnold Arboretum. Every year, the curation department accepts research proposals and welcomes scholars from around the world to study our plants, both in the landscape and our Herbarium of Cultivated Plants. If researchers are unable to visit the collections in person, staff will collect and process samples on their behalf.

Two projects are on the docket this spring, both requiring catkins, leaves, and herbarium specimens from our *Populus* collection. First, we must decide which plants best fit the needs of each research project, assessing the health and viability of each plant to support the requested collections. Next, we prepare Ziploc bags with silica gel (to ensure proper drying) and label them with scientific names, accession numbers and qualifiers, and collection dates. We use pole- and hand-pruners to gather catkins and leaves, cleaning our tools with alcohol between each collection to prevent contamination. Back inside, the specimens dry while we generate research summaries, including detailed information about each plant sampled, and create shipment records in our database. Finally, all materials are shipped out, to both domestic and international destinations. 🌿

Photograph by Jamila dePeiza-Kern



“How can people
appreciate what they
cannot see?” — p. 50

